1964

TECHNICAL HIGHLIGHTS

OF THE

NATIONAL BUREAU OF STANDARDS

Annual Report for:

INSTITUTE FOR BASIC STANDARDS

INSTITUTE FOR MATERIALS RESEARCH

INSTITUTE FOR APPLIED TECHNOLOGY

CENTRAL RADIO PROPAGATION LABORATORY

UNITED STATES DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS
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1964 Technical Highlights of the National Bureau of Standards

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1. GENERAL REVIEW

To an increasing extent, the nature of the world in which we live is being determined by the effects of new discoveries and advances in science and technology. Industrial productivity increases and living standards rise as the technologist finds ways to apply the achievements of science in the development of new products, processes, and resources.

Recognizing the importance of scientific research to the Nation's economic stability and growth, the Secretary of Commerce in January 1964 designated the National Bureau of Standards to serve as a principal focal point within the Federal Government for the application of the physical and engineering sciences to the advancement of technology. At that time steps were also taken to make the Bureau a more effective instrument for performing this function. Two other Department of Commerce activities, the Office of Technical Services (OTS) and a textile technology program in the Office of the Secretary, were transferred to the Bureau, and the resulting overall program, under the general administration of NBS, was grouped into four institutes: Institute for Basic Standards, Institute for Materials Research, Institute for Applied Technology, and Central Radio Propagation Laboratory. These changes were designed not only to provide more effective management but also to permit closer identification of NBS programs with the specific needs of American science, industry, and commerce.

The Institute for Basic Standards (IBS) provides the basis within the United States for a complete and consistent system of physical measurement. It coordinates that system with the measurement systems of other nations, and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation. This measurement system is the foundation of our mass production industry. It is the language by which scientists communicate with each other and by which scientific advances are transferred to the production line, and it provides a basis for the exchange of goods and services in commerce. Principal activities of this Institute include the development and maintenance of the national standards for physical measurement; determination of fundamental physical constants; acquisition of reference data on the properties of matter and administration of a National Standard Reference Data System; research and development on measurement techniques and instrumentation; and the calibration of master standards in terms of the national standards.

The Institute for Materials Research (IMR) conducts a broad range of programs on the properties of matter and materials. Here the objective is to make possible a better understanding of the basic properties and behavior of materials and to make available reliable quantitative data on their performance. From such knowledge come new scientific developments, new production processes, new or improved products, and whole new industries. This Institute devises techniques for preparing experimental materials and for measuring their properties, develops criteria for evaluating materials performance, and develops and distributes standard reference materials.

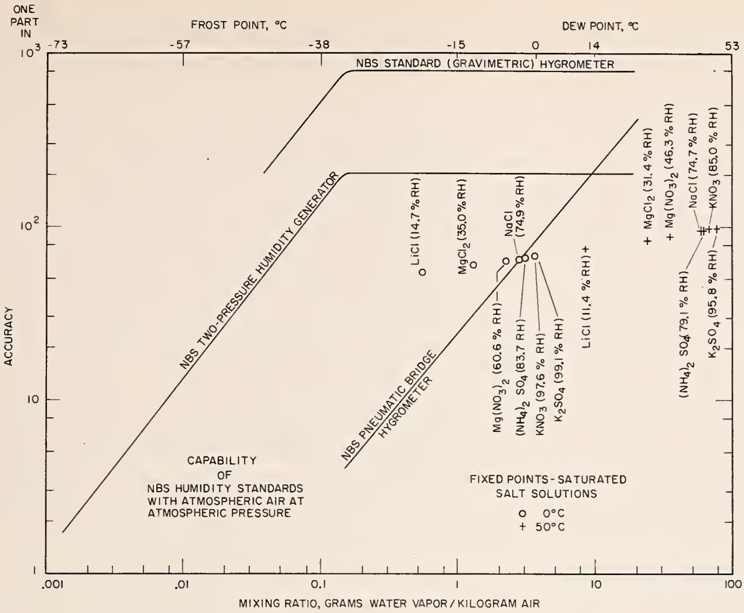
The mission of the Institute for Applied Technology (IAT) is to foster and stimulate the application of technology to national needs, both in government and in industry. This Institute's responsibilities include the development of criteria for evaluating technological products and services, the provision of specialized information services to meet the neeeds of our industrial technology, and studies on the nature of technological change. The Institute seeks to make new technology more readily available to American industry by studying the technical-economic problems involved in technological innovation and by encouraging the developmment of performance standards that provide a sound basis for the acceptance of new technology.

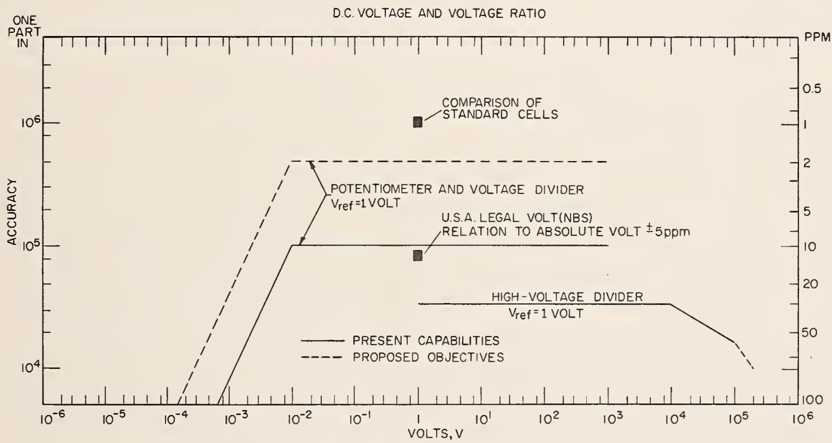
The Central Radio Propagation Laboratory (CRPL), which already existed as a separate unit within the Bureau, has for many years been the central agency of the Federal Government for the collection, analysis, and dissemination of information on the propagation of radio waves at all frequencies along the surface of the earth, in the atmosphere, and in outer space. The Laboratory conducts basic research on the nature of radio waves and the media through which they are transmitted, studies radio propagation mechanisms, provides advisory services on radio-frequency utilization and radio systems; and issues predictions of radio propagation conditions. Because of the tremendous extent of the communications industry and the increasing importance of radio systems in national defense and space exploration, the work of CRPL has come to have far-reaching effects on the Nation's technology.

This report attempts to present the highlights of the programs of the four institutes for the fiscal year 1964. In Section 2, the body of the report, the work of each institute is considered separately, and in each case studies and achievements from the various fields in which the institute is active have been selected for brief presentation. As an introduction to the main body of the report the remainder of Section 1 is devoted to a brief summary of the more important accomplishments and activities of the year at the National Bureau of Standards.

BASIC MEASUREMENTS AND STANDARDS

To insure accurate, uniform measurements throughout the Nation, the Bureau must make its standards available to science and industry through calibration services. As a foundation for this service the Bureau conducts a variety of research programs on the frontiers of measurement science. As science and technology continue their rapid advance, new fields are continually opening up with new measurement requirements; at the same time measurements in the older fields must be made with increasingly greater ac-





The Bureau continued to develop State of the Art graphs in various fields of measurement. Among these were graphs depicting measurement capabilities in the area of humidity, top, and d-c voltage, bottom. **(See page 9)**

curacy and over broader ranges of values. Thus, both in its research and in its measurement services programs, the Bureau tries to anticipate the measurement problems of tomorrow to make sure that measurement "gaps" do not hold back the progress of science and technology.

During the last year, the Bureau's Advisory Committee on Calibration and Measurement Services (Appendix, p. 242), whose members are chosen for their broad knowledge of industrial measurement problems, continued to be of great value in pointing out measurement needs. Particularly pressing was the need for extension of the range of calibration services in the high-frequency and microwave regions. Although initiation of new measurement research projects was curtailed in 1964 because of budgetary limitations, work begun in previous years resulted in the offering of a number of new services. These included: extension of power calibration in WR62 waveguides (12.4 to 18 GHz) to include determination of the calibration factor of bolometer units and of bolometer-coupler units; measurement of the magnitude (range: 0.025 to 1.0) of the reflection coefficient of waveguide reflectors (mismatches) in WR62 waveguides; calibration of three-terminal capacitors at 110 kHz and 1 MHz; determination of frequency stability of signal sources in the range from 0 to 500 MHz; and extension of field-strength calibration services for horizontally polarized dipole antennas from 300 to 1000 MHz.

A significant advance in low-temperature measurement was the establishment of a facility for the calibration of germanium resistance thermometers over the range 2 to 5 °K. This new service should be of considerable value to industry, as germanium resistance thermometry is widely used in low-temperature studies of fuels for rockets and missiles, solid-state devices for space-borne computers, and the phenomenon of superconductivity. As the result of experiments completed during the year, it is expected that a calibration service in the range from 2 to 20 °K will be established in the coming year.

On September 13, 1963, new facilities, providing greatly increased power and range, were dedicated for NBS standard broadcast stations WWVB (60 kHz) and WWVL (20 kHz). These low-frequency stations now provide the most accurate and stable frequency transmissions in the world, enabling scientific laboratories to calibrate their precision frequency sources to an accuracy of better than 1 part in 10^{11} (one thousandth of a second in 3 years). Such accuracy is required in many satellite and missile programs and for basic research on atmospheric and ionispheric phenomena. Previously the two stations had been used only for experimental low-frequency transmissions—WWVB broadcasting from Boulder, Colo., and WWVL from Sunset, Colo. The success of the experimental broadcasts provided technical justification for the construction of new facilities at Ft. Collins and establishment of the stations on a permanent basis. The new stations complement but do not replace the Bureau's higher frequency stations WWV and WWVH, which are sufficiently accurate for many important applications.

The NBS atomic time scales (NBS–A which continuously maintains atomic time and NBS–UA which continuously maintains an atomic approximation to Universal time) were improved during the year by adding two additional clocks to the three-clock system that was previously used for interpolating on these scales between calibrations with the U.S. Frequency Standard. Through addition of the new clocks, the daily precision with which the scales measure time was improved from $\pm 1 \times 10^{-11}$ to $\pm 3 \times 10^{-12}$, and thus the accuracy of either scale after several days becomes limited only by the accuracy of the U.S. Frequency Standard. Since January 1964, the NBS–UA time scale has directly controlled the low-frequency broadcasts of WWVB and WWVL, and indirectly controlled the high-frequency broadcasts of WWV. This has improved the daily stability of these frequency transmissions by almost an order of magnitude. As a result, clocks which are phase locked to the low-frequency broadcasts can maintain time sychronization with NBS–UA to within 10 microseconds.

The Bureau continued to restrict its calibration work, whenever possible, to master standards and high-precision instruments, leaving the calibration of lower-echelon standards to the standards laboratories of industry and the military services. Requests for calibration of lower-echelon standards declined during the year, with an attendant drop in the total volume of calibrations from 75,361 items in fiscal 1963 to 65,353 items in fiscal 1964 (table 1). With this reduction in the calibration load, the Bureau was able to devote a somewhat greater proportion of its resources to the development of new and improved standards and measurement methods.

Efforts to accelerate calibration procedures through use of automation continued. The calibration times for both gage blocks and surveying tapes were substantially reduced by the use of new equipment and electronic data processing. Improved techniques were also developed for the handling and presentation of data and results in the calibration of proving rings, elastic devices used as standards of force. A digital computer now performs the tasks of accurately fitting the data to an equation, statistically analyzing the fit, and printing out tables of load versus ring deflection.

The automation of precise heat measurements was advanced by the completion of an automatic resistance bridge. For automatic determinations of temperature with a platinum resistance thermometer, the bridge has an equivalent temperature precision within 0.0001 °C. Not only does the bridge release a scientist from routine measurements, but its operation is usually more accurate and faster than conventional manual operation, making possible experiments that otherwise would be too difficult to perform.

An important advance in length measurement was the development of a line standard interferometer which uses automatic fringe-counting techniques. This instrument was devised for calibrating graduated length scales such as are used on many types of precision machinery. For such measurements, it makes possible a precision within a millionth of an inch, performing in 15 minutes a calibration procedure that previously would have required as long as 15 hours.

Other research in length measurement was directed toward the development of more accurate methods of measuring long distances, as in the calibration of tapes for surveying missile-tracking sites. In this project the Bureau has been investigating the use of a helium-neon laser as a light source for interferometric measurements of length. In the course of the work, a versatile, convenient-to-use spectrometer was constructed to study laser frequencies. The instrument automatically varies the separation between two interferometer mirrors to scan the spectrum of a light source.

The Bureau continued its program of research to develop procedures for calibrating master gage blocks on a regular basis to 1 part in 10 million.

TABLE 1. *Summary of calibration services*

Area of Bureau activities	Representative items	Public		Government		Totals	
		Number of items	Value	Number of items	Value	Number of items	Value
Electricity	Electrical instruments, standard cells, magnetic materials, resistance, reactance and capacitance standards, d–c to 30 kHz.	7,062	$198,478	1,082	$31,026	8,144	$229,504
Metrology	Light and color standards, photographic lenses, gage blocks and other length standards, refractive index standards, sieves, mass standards, track scales, capacity standards.	34,936	361,320	4,114	130,092	39,050	491,412
Heat	Resistance and liquid-in-glass thermometers, thermocouples, pyrometers.	5,062	156,754	1,224	48,175	6,826	204,929
Radiation physics	Neutron sources and instruments, x-ray and gamma-ray protective materials and instruments, gamma-ray sources, alpha-ray sources, radioactive materials.	231	15,379	243	11,705	474	27,084
Mechanics	Acoustic instruments, accelerometers, vibration pickups, proving rings, load cells, dynamometers, pressure standards, water current meters, gas measuring instruments, fluid meters.	6,090	220,808	1,299	82,359	7,389	303,167
Building Research	Thermal conductivity	34	6,065	12	2,600	46	8,665
Instrumentation	Moisture monitors	3	2,012	1	711	4	2,723
Radio Standards	Electrical and electronic instruments and standards in radio, ultra-high-frequency, microwave ranges.	1,908	168,872	1,512	921,256	3,420	1,090,128
Totals		55,866	$1,129,688	9,487	$1,227,924	65,353	$2,357,612

This work was begun several years ago at the request of machine tool manufacturers, in order to meet the increasingly severe calibration requirements of industry, particularly in the aerospace field. Both highly stable gage blocks and ultraprecise measuring techniques are required. In 1964 the program included (1) a study of the use of polarized light to determine contact error in end standard gaging, and (2) the monitoring of stability samples of steel to determine length changes with aging. Several combinations of materials and treatments have now yielded a dimensional stability better than 0.2×10^{-6} in. per in. over a period of a year, and a few samples have had a stability better than 0.1×10^{-6} in. per in. per year.

Large weights find wide application in the calibration of devices used to measure the thrust of missile and rocket engines. Periodically the weights must be calibrated, so that the equipment is out of service while the weights are shipped to NBS and back. During the year, the Bureau developed a comparative measuring technique which should permit any laboratory to use readily available equipment in the calibration of its own large weights. With a load cell used as a comparator in a double-substitution weighing scheme, precisions of 5 parts per million have been achieved at 10,000 pounds. Over the next few years this technique should save millions of dollars for Government and industry.

A program extending over many years culminated in the development of a precision mercury manometer of extremely high accuracy for measuring pressure in connection with the thermometery standards program. At a pressure of one atmosphere, the manometer provides a precision within 1 part per million and an accuracy within 3 parts per million.

For a number of years the Bureau has performed spectral radiance calibrations in the wavelength region from 250 to 2,600 nanometers (nm) (2,500 to 26,000 Å) with estimated uncertainties of about 8 percent at the shorter wavelengths and 3 percent at the longer wavelengths. Lack of calibrations having smaller uncertainties and extending below 250 nm has been a major limitation to experimental work in plasma and space physics. During 1964 a concentrated effort to improve measurement capability in this area resulted in the development of a spectroradiometer which reduces uncertainties of spectral radiance calibrations by a factor of 5 and extends the range of wavelengths covered down to 200 nm.

Advances in the precise measurement of x-ray wavelengths and the lattice parameters of crystals were made possible by the production of highly perfect crystals of ammonium dihydrogen phosphate in the laboratory. Because of the extremely regular arrangement of their atoms, these crystals, when used as diffraction gratings, have extended the high resolution of measurements in the ordinary x-ray range up to wavelengths of 1 nanometer. At the usual x-ray wavelengths the crystals offer what appears to be the highest resolving power yet reported for any crystals. This improved resolving power will be of great utility as work is pressed toward gamma-ray energies.

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Many of the properties of polymeric systems depend on the distribution of molecular weights of macromolecules in the system, particularly on the extremely low and extremely high parts of the molecular weight distribution. The ultracentrifuge has been a valuable means for determining these molecular weights and their distributions. In 1964 an improved optical system was developed which increased the optical resolution of the ultracentrifuge by a factor of 5 over that of present-day commercial equipment. Also, the accuracy of molecular weight determinations by absorption measurements in the ultracentrifuge was increased by a comprehensive study of the dependence of specific polymeric absorption on concentration.

One of the prime causes of deterioration of polymeric materials is atmospheric oxidation. In a study of oxidation processes, several new techniques, involving gas chromatography and polarography, were developed for measurement of the oxygen consumption of polymers as a function of temperature.

As part of the measurement program, a number of advances were made in methods of precision chemical analysis. For example, the Bureau developed an analytical method, called double radioisotopic dilution, which uses radioisotopic tracers for the analysis of small quantities of the elements. Suitable for use in any standard industrial laboratory, the technique gives sensitivities in the range of 0.1 microgram per gram of sample for the analysis of such elements as silver, cobalt, and iron. Also, through use of coincidence counting techniques, the sensitivity of the analytical method known as activation analysis was increased by a factor of 1,000 for as many as 20 elements. An accurate coulometric method was developed for the determination of potassium dichromate, an important chemical oxidizing agent. By this procedure, one-half-gram samples may be analyzed with a precision of a few thousandths of a percent. A new method of low-level radioisotope dilution analysis was developed and applied to cerium 144. Other methods of analysis completed during the year included a new procedure for the determination of rhodium in uranium alloys, and a method for the analysis of zirconia-yttria refractory materials.

The Bureau continued to cooperate closely with the National Conference of Standards Laboratories, for which it serves as a sponsor. This Conference and its continuing committees bring together representatives from military, industrial, and university standards laboratories, to promote cooperative action on common problems of the management and operation of measurement standards and calibration laboratories. During 1964 the Bureau played an active part in a series of interlaboratory round-robin tests which NCSL has initiated to encourage the development of methods for maintaining a high standard of quality in the services of its member laboratories. Plans were made for a 1964 Standards Laboratory Conference to be held in New York City in October 1964 under the joint auspices of the NCSL, the Instrument Society of America, and the Precision Measurements Association.

To assist supervisors of standards laboratories and others concerned with meaurements at radio frequencies, an intensive, three-week graduate-level course in electromagnetic measurements and standards was offered in the summer of 1963 by the NBS Graduate School in association with the University of Colorado.

An important medium for the exchange of information on electronic measurements was the Conference on Precision Electromagnetic Measurements, held in June 1964 at the NBS Boulder Laboratories. The Conference was sponsored by the Institute of Electrical and Electronics Engineers, the International Scientific Radio Union, and the NBS Institute for Basic Standards; it was also supported in part by the National Science Foundation. Forty-seven papers were presented during the four-day meeting, which was attended by more than 600 scientists and engineers from industry, universities, and government.

In conformance with a policy adopted in fiscal 1963, all results of NBS calibrations and tests were issued in report form, supplemented by a letter of formal certification when required by law or special conditions. The new reporting policy was well received, and it is believed that it has been helpful to industry in clarifying the respective responsibilities of manufacturer and user in maintaining instrument accuracy as based on NBS calibration of a master standard.

The preparation of charts showing NBS measurement capabilities for various physical quantities was continued as an aid to the planning of NBS measurement services. Several of these charts are reproduced on page 3.

STANDARD REFERENCE DATA

"Standard reference data" is defined as critically evaluated data on the physical and chemical properties of materials, authoritatively documented as to reliability, accuracy, and source. The evaluating process includes the definition of "best" values for selected properties and establishment of confidence limits for these values.

At the close of fiscal 1963, NBS was given responsibility for administering and coordinating the National Standard Reference Data System (NSRDS), established at that time by the Office of Science and Technology. The aim of the System is to develop a storehouse of standard reference data to assist in the advancement of science, technology, and the economy. It will provide critically evaluated data in the physical sciences on a national basis.

According to present plans, the data input to the NSRDS will come from scientists in many different locations who will comprehensively review the literature in their fields of specialization and critically evaluate the data it contains. Evaluated data, classified and stored at NBS, will be disseminated through a series of services tailored to user needs in science and industry.

The first year of the NSRDS was mainly devoted to planning the data-compilation program. The field of physical science was tentatively divided into a number of categories, each covering an area broad enough to include a large number of standard reference data-compilation activities. Programs were initiated in the following seven of these technical categories: Nuclear data, atomic and molecular data, solid state data, thermodynamic and transport data, chemical kinetics, colloid and surface properties, and mechanical properties of materials. Other programs are to be added as available resources permit. In each of the seven areas a survey of existing data-compilation activities has been made and is being followed by a detailed appraisal of needs and priorities for new or expanded programs. Competent groups are being sought to undertake the high-priority activities. In some cases these groups are within NBS; in other cases they are in industrial, university, or other Government laboratories.

The Bureau continued to be active in research to develop standard reference data, a field in which it has made numerous contributions over the years. In the course of this work, two new research techniques were devised that provide a powerful double-edged tool for exploring atomic structure. Through application of these techniques, physicists were for the first time able to study effectively the excitation of atoms and molecules in the intermediate energy range—from energies of about 10 to 1,000 electron volts. This type of excitation is normal in the high-temperature plasmas that occur in thermonuclear devices and stellar atmospheres.

The two new techniques utilize previously unavailable sources of photons and electrons in the intermediate energy range. In the first case, the Bureau's 180-million electron-volt synchrotron has been modified to make it possible to extract the very-short-wavelength ultraviolet light generated by the machine, with photons in the intermediate range, and to study the absorption of

The NBS high resolution electron spectrometer was displayed at the Annual Meeting of the National Academy of Sciences. This new analytical tool has provided a breakthrough in detecting and measuring atomic properties.
(See page 10)

this light by various materials. The second technique uses a new ultra-high-resolution electron spectrometer as a means of accelerating and controlling electrons so that they travel at nearly identical speeds. With these techniques Bureau scientists have observed hundreds of new atomic energy levels which exhibit properties that are absent or not relevant in other energy ranges. Many of these levels belong to previously unknown negative ions. Other atomic data can now be obtained which are of great importance to space and chemistry research, thermonuclear control, and studies of the earth's upper atmosphere.

A technique was also developed for accurately measuring binary gaseous diffusion coefficients over a wide temperature range. With this technique it is possible to make measurements to a precision of 0.5 percent over a temperature range of 77 to 373 °K. To date, measurements have been completed on oxygen, nitrogen, argon, neon, and krypton diffusing in helium.

An ellipsometric technique was used to determine the optical constants of iron single-crystal surfaces in ultra-high vacuum as a function of wavelength in the region of 360 to 700 namometers. Because of the extremely clean crystals used, these data are thought to be the best optical-constant values ever obtained for iron in this spectral range. The new data will be of definite value to theorists who are seeking additional knowledge about transitions between energy levels in metals.

As in previous years, the Bureau conducted a number of data centers for compilation and storage of critically evaluated data in such areas as chemical thermodynamics, atomic transition probabilities, atomic cross sections, and cryogenics.

The Cryogenic Data Center distributed an estimated 18,000 items of NBS literature in response to some 1,900 requests, and over 6,000 new references were coded and entered into the Center's storage and retrieval system. Data from the scientific literature on the thermophysical properties of materials were critically evaluated and compiled at the Center with support from the National Aeronautics and Space Administration and the NSRDS. Also completed during the year were extensive tables of thermodynamic data for carbon monoxide, a bibliography on the thermophysical properties of argon, and a compilation of the dielectric constants of cryogenic fluids.

ENGINEERING MEASUREMENTS AND STANDARDS

As part of its increased emphasis on engineering standards the Bureau is seeking to extend its cooperation with recognized standardizing bodies in the development of codes, specifications, standards of practice, and methods of test for technological devices, products, and services. The Bureau is in a position to make significant contributions to such engineering standards because of the active participation of its staff members in the work of numerous technical societies and standardization groups such as the American Standards Association, the American Society for Testing and Materials, the Optical Society of America, the Society of the Plastics Industry, and the

Electrochemical Society. In this cooperative activity, the Bureau assists by conducting research to provide test methods, data on materials, and measurement standards; the sponsoring organization supplies other technical data and promulgates the finished documents in the form of codes, specifications, or engineering standards. Only a few standards of this kind, mostly concerned with safety and assigned by law to the Department of Commerce, are set or promulgated by the Bureau. An example is the recent assignment to NBS of the responsibility for developing specifications for Seat Belts for Use in Motor Vehicles. These specifications are to be promulgated by the Secretary of Commerce in accordance with the requirement of Public Law 88–201.

In a somewhat different category are the Commodity Standards which are published by the Bureau. These are voluntary trade standards that define quality levels for products and aid in holding variety to a minimum. When an industry group decides to initiate a Commodity Standard, it submits a tentative draft to NBS and requests assistance in its development and issuance. The Bureau acts as a secretariat in the further development of the standard, determining its feasibility and securing general acceptance of its provisions by the industry. The standard is then published by NBS either as a Commercial Standard (a quality-level standard) or as a Simplified Practice Recommendation. During fiscal 1964, nine Commercial Standards and five Simplified Practice Recommendations were issued.

The Bureau also plays an active role in the development of Government purchase specifications. During fiscal 1964, at the request of the General Services Administration, the Bureau accepted responsibility for preparing and maintaining one additional Federal Specification, making a total of 153 for which it now has this responsibility. The Bureau also reviewed approximately 550 proposed specifications both for GSA and for other agencies to determine their suitability for use by the Federal Government.

In the last year, the Bureau conducted a number of studies to develop performance criteria. For example, a method for measuring the tensile strength of dental amalgam was developed in which specimens are stressed by high rotational speeds. The method is especially well suited for observing the strength of small specimens of the material during hardening or setting.

Studies of rental car and truck odometer accuracy continued. In cooperation with representatives of the automotive industry, detailed test procedures were developed for vehicle odometers. These procedures have now been incorporated in State weights and measures requirements for rental cars. As a result, odometers on all cars furnished to rental fleets will comply with tolerances by the end of 1964, and eventually all automobiles manufactured in the United States will more accurately register distance traveled.

Accumulations of ice or moisture within the walls of refrigerated structures seriously reduce the insulating value of the walls and often lead to physical injury to the structure. During the year the Bureau developed criteria which establish minimum properties of the vapor barrier, the insulation, and the interior finish required to avoid moisture condensation. With these criteria as a guide, designers of cold-storage facilities can avoid condensation difficulties in the future.

Asphaltic roofing materials are usually so opaque that it is difficult to evaluate them by conventional optical methods. However, when x rays were used to produce images of the microstructure of asphalt-containing specimens, Bureau scientists were able to determine the distribution of reinforcing materials in asphalt films and mats, as well as the origin and development of failures in shingles and other structures. This technique not only reveals many details of the mechanism of deterioration, but is often able to demonstrate intrinsic weaknesses in design or formulation before they become apparent by other methods of analysis.

The U.S. Standard for the Colors of Signal Lights was published in 1964 as an NBS Handbook. This recommended standard was prepared to help bring specifications used in this country for signal light colors into agreement with international usage as embodied in the recommendations of the International Commission on Illumination (CIE). With the growth of international travel, the signal lights of each country are coming to be used more and more by the citizens of other countries, and a need for international standardization has become apparent. The standard was developed by the U.S. National Committee on the Colors of Signal Lights under the sponsorship of the U.S. National Committee of the CIE. NBS cooperated in this effort by providing the technical data upon which the Standard is based.

During fiscal year 1964, the Bureau tested 51,784 items ranging from light bulbs to concreting materials (table 2). Most of the tests were on items purchased by other Federal agencies that lacked the facilities to make the tests themselves.

STANDARD REFERENCE MATERIALS

During fiscal year 1964 the Bureau distributed to other laboratories 78,479 samples of standard reference materials having a value of $573,608 (table 3). These standard materials are certified either for chemical composition or for a particular physical or chemical property, such as radioactivity, viscosity, or melting point. They thus provide a basis for making uniform measurements of heat and temperature, for calibrating instruments that control the composition of metals used in rockets and jet engines, for calibrating radioactive nuclides, and for controlling the composition of motor fuels.

More than 600 different standard materials currently are available—principally chemicals, ceramics, metals, and radioactive nuclides. New standard materials added during the year included a highly purified uranium oxide, a variety of copper-base and steel standards for spectrochemical analysis, a cesium-barium 137 point source, and a titanium-base alloy.

During the last year, the Bureau's standard reference materials program was critically evaluated to assure that the program will provide maximum assistance to the Nation's advancing science and technology. A result of this survey was the establishment of an Office of Standard Reference Materials within the Institute for Materials Research. This new Office will provide a

TABLE 2. *Summary of testing services*

Area of Bureau activities	Representative items	Public		Government		Totals	
		Number of items	Value	Number of items	Value	Number of items	Value
Electricity	Dry cells, hearing aid batteries, storage batteries			472	$8,161	472	$8,161
Metrology	Lamps			2,731	35,400	2,731	35,400
Analytical and Inorganic Chemistry.	Chemical analysis	19	$2,997	155	7,820	174	10,817
Mechanics	Mechanical devices			2,045	22,033	2,045	22,033
Polymers	Paper, textiles, rubber, leather and plastic products	1	201	6,486	207,248	6,487	207,449
Metallurgy	Metals and alloys	5,507	20,751	66	2,211	5.573	22,962
Mineral Products	Ceramic products, glass			7	1,050	7	1,050
Building Research	Building materials, air filters, fire extinguishers, heating and air conditioning equipment, paints and other surface coatings.	6	4,059	1,315	53,718	1,321	57,777
	Cement	3,792	7,345	11,202	452,326	14,994	459,671
	Concrete and concreting materials			13,339	163,001	13,339	163,001
Instrumentation	Security filing cabinets			6	3,403	6	3,403
Physical Chemistry	Synthesis of sugar and related products	4,335	5,493	300	375	4,635	5,868
Totals		13,660	40,846	38,124	956,746	51,784	997,592

Table 3. *Standard reference materials issued*

Area of Bureau activities	Description of samples	Public		Government		Totals	
		Number of samples	Value	Number of samples	Value	Number of samples	Value
Metrology	Glass filters	35	$1,750			35	$1,750
	Resolution test charts	15,640	3,128	757	$152	16,397	3,280
	Calibrated glass spheres	340	3,232	21	200	361	3,432
	Photometric standards	344	18,955	74	4,305	418	23,260
	Spectrophotometric standards	73	6,903	22	2,217	95	9,120
	Color temperature standards	36	1,970	9	315	45	2,285
	Reflectance standards	68	1,194	8	176	76	1,370
	Opacity standards	142	4,515			142	4,515
	Gloss standards	19	358			19	358
	Signal glass limit standards	77	5,344	17	1,122	94	6,466
	Haze standards	189	3,064			189	3,064
	Spectral radiance standards	3	840	29	8,670	32	9,510
	Total irradiance standards	4	316	15	1,185	19	1,501
	Spectral irradiance standards	83	26,735	44	14,165	127	40,900
Radiation Physics	Radioactive samples	440	13,379	180	6,576	620	19,955
Chemistry	Hydrocarbon blends	36	432			36	432
	Hydrocarbon	55	1,340	5	165	60	1,505
	Cells	17	3,300	2	450	19	3,750
	Spectrographic	6,451	112,355	437	7,685	6,888	120,040
	Composition	24,789	151,015	1,104	6,431	25,893	157,446
	Metal-organic material	901	9,010	180	1,800	1,081	10,810
	Sucrose and dextrose	324	1,296	41	164	365	1,460
	Labeled carbohydrates	4,335	5,493	300	375	4,635	5,868
	Special nuclear standards	650	10,699	99	1,647	749	12,346
Mechanics	Viscosity oils	1,035	17,317	116	1,725	1,151	19,042
Polymers	Standard fading	702	10,214	39	516	741	10,730
	Reference paper	423	1,692	14	56	437	1,748
	Rubber	7,215	53,174	69	513	7,284	53,687
	Phosphor reference	127	381	6	18	133	399
	Polystyrene	222	3,552	65	1,050	287	4,602
Metallurgy	Unalloyed titanium	138	1,380	6	60	144	1,440
	Gas analysis	230	2,300	9	90	239	2,390
	Standard thickness samples for electroplated coatings	5,507	20,751			5,507	20,751
Inorganic Solids	Soda-lime-silica glass	26	1,040	1	40	27	1,080
Building Research	Surface flammability	64	512			64	512
	Paint pigments	42	126	12	36	54	162
	Cement	3,814	11,889	202	753	4,016	12,642
Total		74,596	510,951	3,883	62,657	78,479	573,608

national focal point for a wide spectrum of reference materials activities. Present-day measurement systems, which often are more sophisticated than those of a decade ago, require increasingly more complex and more highly characterized materials for their calibrations. The Office of Standard Reference Materials will serve as a clearinghouse for such requirements throughout the country and, particularly in the field of materials science, will provide leadership to make measurements meaningful. To closely link the standard reference materials program with research efforts in other laboratories, NBS Miscellaneous Publication 260 (published in successive sections) was initiated as a medium for broad and rapid dissemination of the results of standard materials investigations at the Bureau.

Development of new and improved analytical techniques is an important part of the standard materials program. During the year, an x-ray fluorescence spectrographic method of analysis, giving highly accurate results, was developed and applied to the analysis of brass standard reference materials in solution form. The data obtained by this method compare well with the results of chemical analysis of the same samples, although the x-ray method is considerably faster.

Another advance in spectrographic analysis was the development of a device for the spark excitation of atomic emission spectra in atmospheres other than air. With this device, analyses can be performed in a controlled argon atmosphere as rapidly as in air. The result is to reduce the number of standard materials required to calibrate analytical equipment inasmuch as a single set of calibration curves obtained by spark excitation in argon can be applied to the analysis of several related alloys.

RADIO PROPAGATION

The Central Radio Propagation Laboratory continued to conduct a broad range of studies directed toward the efficient use and conservation of the radio spectrum. One of the main areas of CRPL research concerned the ionosphere, the ionized region of the upper atmosphere covering the height range from roughly 50 to 1000 kilometers above the earth's surface. The constant changes that occur in the heights of these layers have important effects on radio wave propagation.

The total eclipse of the sun on July 20, 1963, which was visible over much of northern North America, provided an excellent opportunity for observation of the effects of the eclipse on the ionosphere. Vertical soundings of the ionosphere were made by several laboratories, from a total of 22 locations across the continent, providing the most extensive set of ionospheric observations ever made for a solar eclipse. CRPL's analysis of the data showed a well-marked geographical pattern of variation in the F region of the ionosphere with eclipse time, and maps of this variation are being prepared for use in testing theories of the physica lprocesses of the ionosphere.

CRPL played an important part in the planning, coordination, and execution of programs for the International Years of the Quiet Sun (IQSY). This international scientific effort will continue through 1964 and 1965, a period chosen because it is at the minimum of the sunspot cycle, when solar disturbances are likely to have the least effect on the ionosphere and thus to cause the least interference to radio propagation. The IQSY program is coordinated domestically by the National Academy of Sciences and internationally by committees of the International Council of Scientific Unions. Current CRPL contributions include coordination and direction of ionosphere and airglow projects, operation of the World Warning Agency which makes final selection of worldwide geophysical alerts, operation of the Western Hemisphere Radio Warning Service, and operation of the World Data Center-A for Airglow and Ionosphere.

In October 1963 a program of high-altitude nuclear detection studies was begun at CRPL under the sponsorship of the Advanced Research Projects Agency. This program will be concerned with the development and evaluation of ground-based detection techniques for the planning of systems for use in connection with the Limited Test Ban Treaty.

DATA-PROCESSING SYSTEMS

Automatic systems for the processing and storage of information are playing an increasingly important role both in industry and in the operations of the Federal Government. In this rapidly advancing field, the information technology laboratory of the Institute for Applied Technology serves as a center within the Government for research, development, and provision of technical services. It conducts investigations leading to the development of new and better tools for information processing, and it assists other agencies in devising information-processing systems that will more effectively meet their needs. It also operates a Research Information Center and Advisory Service on Information Processing under the joint sponsorship of NBS and the National Science Foundation, providing information on current research and development in the field of Government and industry.

In 1964, assistance to other Government agencies in problems of information processing covered a wide range of activities. Representative projects included assistance to the Defense Communication Agency in devising and using a computer program to simulate the Defense Communication System; development of a data-processing system for use by CRPL on the Advanced Research Projects Agency project on the detection of nuclear events in space; development of a high-capacity multipurpose data conversion and editing system for the Office of Emergency Planning; development of plans for a global range information processing and control system in support of future orbital and space programs of the Air Force; continued assistance to the Navy Bureau of Supplies and Accounts on problems of procurement; technical assistance to the Weather Bureau on the processing of data from the NIMBUS satellite series; research for the Naval Training Device Center on techniques for automatically producing three-dimensional terrain information from stereophotographic information; advisory service to the Internal

Revenue Service in a study of the efficiency of methods of processing tax return information; a study conducted for the Department of the Interior on the feasibility of applying automatic data-processing techniques to the development and management of a nationwide plan for outdoor recreation facilities; and technical assistance to the Public Housing Administration in the processing of reports relating to low-rent housing applications.

Work sponsored by the U.S. Army Personnel Office resulted in the development of the Vigilometer, a computer-type research apparatus for testing and recording the alertness of human subjects. The machine was designed to determine how the instrument-monitoring performance of Army personnel is affected by such factors as time on duty, distractions, and characteristics of displays to be monitored. The Vigilometer should also be useful to industry in developing information on optimum work methods and conditions.

CLEARINGHOUSE FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION

As the result of action by the Federal Council for Science and Technology, a Clearinghouse for Federal Scientific and Technical Information was established within the Institute for Applied Technology in February 1964. The Clearinghouse provides a central point of contact from which industry and the technical community may obtain information on Government activities in the physical and engineering sciences. Such a facility should be of major importance in assisting American industry to benefit from defense and space research.

In effect, the new activity is an extension of the information dissemination program of the Institute's Office of Technical Services, which now operates the Clearinghouse. Specific functions of the Clearinghouse are as follows: (1) To make available all unclassified and unlimited Government technical reports to industry and the technical community; (2) to develop a unified Government-wide index to unclassified scientific and technical literature and to provide prompt reference service; (3) to provide referral service to sources of technical expertise in the Government technical community; and (4) to provide information concerning Government-sponsored research and development currently under way.

ADVISORY SERVICES

The advisory services performed by the Bureau are a natural result of the broad scope of its program and the special competence of many of its staff in the physical and engineering sciences. Numerous and diverse services of this kind are rendered to other Federal agencies, to State and municipal governments, and to various industrial organizations. For example, during the last year, a survey of the lightning protection problems associated with the new Rayburn House Office Building was made for the Architect of the Capitol, and technical assistance was given the Army in the selection of material for the Saturn rocket installation at Cape Kennedy, Fla.

A forward step in intra-Government cooperation was the establishment of a Computer Sharing Exchange and a Computer Service Center at the Bureau on an experimental basis. The new facilities were created at the request of the Bureau of the Budget, which has found that great savings in both time and money can be realized through computer sharing. The Sharing Exchange will coordinate requests of Federal Government agencies in the Washington, D.C., metropolitan area for help in locating appropriate computer time and services for their essential work. The Center will provide electronic equipment and personal services at cost to participating agencies.

Weights and measures continued to be an important area of assistance to State and municipal governments. Although the Bureau does not have regulatory powers, it offers technical advice and consultation to local regulatory bodies, and its calibrates and adjusts State standards of weights and measures. A major medium of cooperation is the National Conference on Weights and Measures. Over 600 delegates from 41 States, Puerto Rico, Canada, and the United Kingdom attended the 49th annual meeting of this Conference, held in Washington, D.C., in June 1964, under NBS sponsorship.

At the request of the legislature of Mississippi, the only State that still had no comprehensive weights and measures law, the Bureau conducted an intensive survey of weights and measures conditions in that State. The conditions revealed by the survey led directly to the enactment, by Mississippi in March 1964, of the National Conference on Weights and Measures Model State Weights and Measures Law.

Within the Institute for Applied Technology, two important avenues of Bureau-industry cooperation were the Textile and Apparel Technology Center and the Office of Invention and Innovation. The Center's program is an attempt to catalyze and expand the textile and apparel industry's own efforts to create and develop the technical institutions it needs for economic development. The Center cooperates with trade associations, universities, and other organizations to identify obstacles to technical innovation in the textile industry and to formulate programs to overcome these. It also collects and disseminates technical information of importance to the industry, and it supports studies of the relationship of technology to the economics of the textile and apparel industry.

The Office of Invention and Innovation encourages inventors' programs as a means of stimulating regional industrial activity based on new technology. Pilot programs are now under way in Arkansas, Illinois, Missouri, and Nebraska, with others scheduled for the midwestern area.

Other valuable means of Bureau-industry cooperation were the Research Associate Plan and the donor program. Under the Research Associate Plan, technical, industrial, and commercial organizations can support work at the Bureau that is of special interest to them, yet of sufficient general interest to justify use of Government facilities. The work is done by research associates who are paid by the sponsor but otherwise function as members of the Bureau staff. At the present time the following groups are supporting research associates at the Bureau:

Sponsor	*Field of Activity*
American Dental Association	Dental research
American Electroplaters' Society	Galvanic effects associated with coating failure
	Properties of electrodeposited copper
American Society for Testing and Materials	Cement and concrete reference laboratory
American Standards Association	Codes, specifications, and standards
Asphalt Roofing Industry Bureau	Asphalt roofing research
Bone Char Research Project, Inc.	Studies of adsorption and adsorbents
Calcium Chloride Institute	Hydration of portland cement
NBS—Joint Committee on Chemical Analysis by Powder Diffraction Methods: ASTM, American Crystallographic Assoc., Institute of Physics (British), National Assoc. of Corrosion Engineers	Standard x-ray diffraction powder patterns
National Academy of Sciences–National Research Council	Atomic physics
Porcelain Enamel Institute	Porcelain enameled metals

The donor program was authorized in 1950 by Public Law 619 under which the Bureau may accept funds for the purpose of furthering its work. This arrangement permits individuals as well as technical, industrial, and commercial organizations to support work at the Bureau when the results are expected to be of value to the general public. During the past year, the following projects were supported by gifts:

Donor	*Field of Activity*
American Iron and Steel Institute	Durability of steel pilings
International Astronomical Union	Publication costs of "The Solar Spectrum"
International Commission on Radiological Units	Support of ICRU Secretariat
National Association of Home Builders	Building materials research
The Expanded Shale, Clay, and Slate Institute	Creep and shrinkage of concrete containing expanded shale aggregate

GENERAL RESEARCH

In addition to those research activities that are directly related to the missions of the four institutes, the Bureau conducts a broad program of exploratory or background research in the physical sciences. The primary purpose of this work is to maintain and strengthen the general scientific competence of the staff so that the Bureau can keep abreast of new developments in many fields, select the most effective techniques for solving problems, and utilize quickly the results of scientific work elsewhere. The following paragraphs illustrate the diversity of the background research program during the year.

In work sponsored by the Advanced Research Projects Agency, NBS scientists found that at very low temperatures the semiconductor strontium titanate becomes superconducting—that is, it completely loses its electrical resistance. Although superconductivity has been observed in at least one other semiconductor (germanium telluride), it is believed that this was the first observation of superconductivity in an oxide-type semiconductor. Because the superconducting properties of the material can be varied with treatment, further study of this and related materials should lead to a more complete understanding of the nature of superconductivity. Such knowledge could be of immediate value in the development of extremely high-field industrial magnets, highly compact superspeed computers, and possibly other applications.

Until recently metals and alloys were the only substances known to be superconducting. Unfortunately these materials have a complex structure that is not completely understood by theorists. Semiconductors, on the other hand, are relatively simple materials which can be more easily treated theoretically. Moreover, the composition of semiconductors can be precisely controlled. Thus, using semiconducting materials, scientists can now study the effect of both composition and treatment on superconductivity, and they can begin to predict what semiconducting materials will be superconductive. Studies of this kind should round out present knowledge of superconductivity and eventually lead to the development of more useful superconducting materials with controlled properties.

Because of the enormous complexity of most plasmas, there has been a lack of accurate, convenient diagnostic techniques that might provide a better understanding of plasma characteristics. Recently the Bureau developed a new form of plasma—the brush-cathode plasma—which is both stable and uniform and which thus lends itself to precision measurement of its characteristics. Extensive studies of this plasma were under way.

Research in culvert hydraulics, sponsored by the Bureau of Public Roads, produced designs for culvert inlets which substantially improve the water-carrying capacity of highway culverts. Inlet designs developed in the study will enable engineers to use culverts of smaller size and cost for any desired capacity. As Federal and State costs for construction of culverts and similar drainage structures for highways are approximately $400,000,000 a year, this work promises to yield important savings.

For a number of years the Bureau has been conducting an extensive program of experimental and theoretical studies in polymer crystal physics. The overall objective of this work is to gain an understanding, in terms of physical concepts, of the behavior and performance characteristics of semicrystalline polymers in bulk.

Many polymers crystallize in the form of lamellar crystals many microns in length and width, but only 10 to 30 nanometers thick. As the axes of the polymer molecules are largely perpendicular to the large flat faces of the crystal, it appears that the polymer chains must be folded to form the crystal. During 1964 two significant advances were made in the theory of these chain-folded polymer crystals. First, a theory of the rate of thickening of chain-folded lamellae on isothermal storage was refined and tested experimentally in low-angle x-ray diffraction measurements on polyethylene at the crystallization temperature. Secondly, the theory of the rate of formation of chain-folded lamellae was refined to include estimates of surface roughness.

Polymer adsorption is an important factor in the fabrication of numerous composites such as glass fiber-reinforced plastics, tires, most adhesive joints, and many protective coatings. Only a few segments of the polymer molecule may actually be adsorbed on a surface; these segments then act as anchors for the rest of the molecule, which takes the form of loops dangling in the solution. Recent NBS work has shed new light on the mechanism of this adsorption process. Measurements were made of the extension of a polymer molecule away from the adsorbing surface, and a new theory was worked out for low-surface-coverage adsorption. The resulting information should be useful in the development of improved composites using plastic materials.

With the partial support of the Advanced Research Projects Agency, the Institute for Materials Research has been conducting an accelerated program of research on crystal growth and characterization. This program is designed to provide basic information on the nature of matter as well as information of more immediate utility in military and space applications. During the year, significant advances were made in the growth of pure crystals from solution. Ammonium dihydrogen phosphate crystals of extremely high physical perfection were grown and the perfection of their structure demonstrated by x-ray diffraction and etch-pit techniques. The growth of these crystals was observed visually and found to involve the movement of spiral steps, elliptical in shape and emanating from screw dislocation centers on the prism faces; on the pyramid faces of the crystal no dislocation centers were observed and growth proceeded by the movement of essentially straight steps from the edges of the face toward the center. This program also resulted in the production of sizable single crystals of sparingly soluble salts by interdiffusion of the component ions or oxidation-reduction reactants in silica gel media.

Interest in the chemistry of boron hydrides has been widespread in recent years because of their value as reducing agents in chemistry and their potential utility as chemical fuels and fuel additives. In 1964 difluoroborane (HBF_2), the first example of a partially fluorinated boron hydride, was synthesized at NBS. Although a few boron hydrides are known in which one or more hydrogen atoms have been replaced by halogens, no fluorine derivatives of this type had been prepared before. Difluoroborane and compounds related to it are now being investigated intensively from a number of points of view, including those of descriptive chemistry and reaction mechanisms. This group of compounds provides a model system useful in studying the effect of substitution on the structure and reactivity of boron hydrides. Moreover, availability of boron hydride in quantity will permit detailed investigations of complex reactions believed to involve fluorinated hydrides as short-lived intermediates.

Today most of the buildings in the United States use asphalt roofing. For this purpose, asphalts are hardened by blowing with air at high temperatures (300 °C) and at high flow rates. Research showed that by replacing air with more reactive oxidants such as oxygen and nitrogen dioxide, asphalts can be hardened at a much faster rate using temperatures 150 °C below those employed commercially, reduced gas flow rates, and simple experimental apparatus. The roofing-grade asphalts produced with these oxidants were more stable to photochemical oxidation than were commercial asphalts from the same asphalt flux.

The best least-squares method for estimating the slope of a straight line through the origin is well known and is readily applied when the correct weights of the plotted data are known. In practice, however, the weights are usually known only approximately. The Bureau has recently completed a study of the relative advantages and disadvantages of the most important weighted estimates of straight-line slope when they are used without the correct weights being known. The results of this study will guide data analysts in choosing the best method of estimating the slope in a particular situation.

INTERNAL TECHNICAL SERVICES

Construction of a high-flux reactor facility and associated laboratories was begun at the Bureau's new site at Gaithersburg, Md. The new research reactor, to be known as the NBSR, will be used to advance the measurement, analysis, and understanding of radiation effects on substances of all kinds. It will be operated by the Institute for Materials Research and will be shared with other Government agencies in the Washington area having the same general requirements as the Bureau.

Installation of the NBS linear accelerator, Linac, began at Gaithersburg in the spring of 1964. This accelerator will produce one of the world's most intense electron beams with energies up to 100 million electron volts, making it possible for the Institute for Basic Standards to enter new areas of nuclear and atomic physics. At the close of the fiscal year almost all major components of the accelerator were in place, and various subsystems were being installed. Among these was a data-handling system that provides concurrent on-line processing of data from several independent experiments. This versatile system will eliminate the need for costly special-purpose analyzers which are subject to rapid obsolescence.

INTERNATIONAL ACTIVITIES

On an international basis, the Bureau represents the interests of the Government and American science in matters dealing with the establishment and maintenance of standards and the establishment of values for scientific constants. Most of this work is done through participation in a large number of international groups such as the General Conference on Weights and Measures, International Union of Pure and Applied Physics, International

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Union of Pure and Applied Chemistry, International Scientific Radio Union, International Commission on Illumination, and International Organization for Standardization.

The Bureau has been actively participating, through the American Standards Association, in the development of pan-American standards for various commodities such as textiles; iron and steel; cement and concrete; hides, leather, and tanning materials; and electrical equipment. This program is basic to the economic development of the Latin American countries and to the expansion of trade among these countries and between them and the United States. Several of the Latin American countries have requested and received assistance in the field of weights and measures. During 1964 translations of NBS weights and measures publications into Spanish and Portuguese were completed. New metric prototype standards, suitable for use as the national standards of developing countries, were procured for demonstration and training purposes.

Another form of international cooperation is the reception of foreign scientists as guest workers or visitors, and the training of foreign specialists in the Bureau's laboratories. During the last year, 464 scientists from 54 countries came to the Bureau as visitors. In addition, 36 trainees and 30 guest workers were received from abroad.

The Bureau was host to a team of five Soviet metrologists during their month-long (January 8–February 2, 1964) visit to this country. The Soviet visit was in exchange for the visit of a U.S. metrology delegation, composed largely of NBS scientists, in June 1963. These visits were conducted under the terms of a United States-U.S.S.R. agreement for the interchange of information and exchange of visits by teams in 13 fields of technology. The U.S. State Department, under whose general control the exchange program is conducted in this country, requested that the Bureau arrange for the exchange of persons from the area of high-precision measurement standards. Before leaving this country, the Soviet delegation agreed in principle with NBS on the desirability of cooperation in (1) exchange of data on observations of standard time and frequency signals from various radio stations, (2) exchange of calibration information to compare various electrical and electronic quantities, and (3) exchange of NBS publications with those of the U.S.S.R. Committee on Standards, Measures, and Measuring Instruments. It was recommended that the measurement exchanges be coordinated through the International Bureau of Weights and Measures.

In 1964 a total of $728,000 was granted to scientific laboratories in India, Israel, and Pakistan for the support of work directly related to the Bureau's mission. These grants are financed from excess balances of local-currency funds accruing to the United States from the sale of surplus farm products in past years; thus they create no drain on the cash budget of the United States. In addition to the scientific findings that have resulted from the grants, the program has been of notable value in stimulating communication between American scientists and those of the countries involved.

As previously indicated, a major reorganization of the scientific activities of the Department of Commerce occurred in January 1964 involving NBS, the Office of Technical Services, and the textile technology program associated with the Office of the Assistant Secretary for Science and Technology. All of these activities were combined at that time in a substantially reorganized National Bureau of Standards with broadened responsibilities for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce.

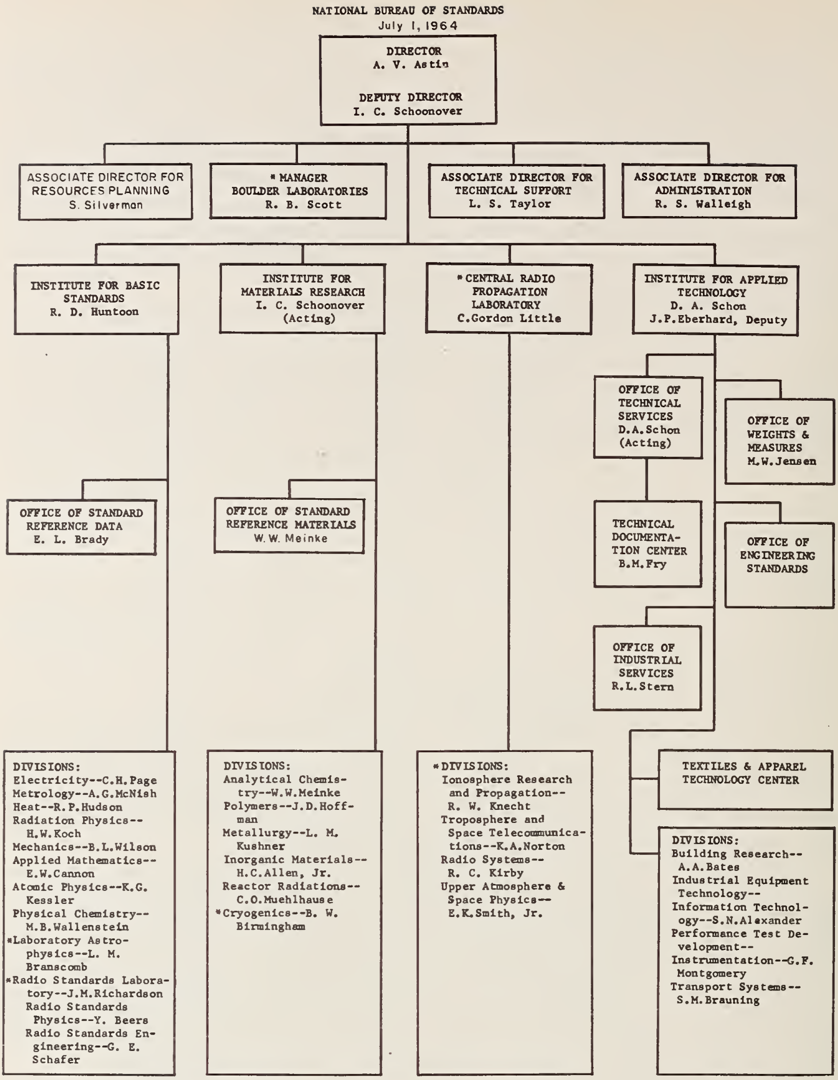
To facilitate coordination and management of the enlarged NBS program, the four institutes were established, each having its own Institute Director. The first two institutes—Institute for Basic Standards and Institute for Materials Research—were formed by regrouping existing NBS divisions which have programs involving similar technical objectives, staff, and facilities. The third institute, Institute for Applied Technology, brought together previously scattered activities related to stimulation of technological progress in industry. These included the extensive technical information services of the Office of Technical Services and the textile technology program, as well as certain industry-oriented NBS programs. The Central Radio Propagation Laboratory, the fourth institute, represented a continuation of a separate program that had been under way for many years.

The functions and activities of the four institutes are discussed on pages 31, 123, 165, and 197. The new organizational alinement (see p. 26) will enable the Bureau to meet both new and longstanding responsibilities with improved focus on the special needs of science and industry for NBS services. For a more complete organizational listing see appendix 1.

Construction of Phase I of the Bureau's new laboratories near Gaithersburg, Md., was completed during the year. The two buildings involved, the Engineering Mechanics Laboratory Building and the Boiler Plant, were occupied and placed in operation. However, much work remained to be done to complete and calibrate the large force-measuring machines that were being erected in the new mechanics laboratory, and the 12-million-pound testing machine for use in this building had not yet been delivered.

Phase II of the Gaithersburg construction includes four buildings to house the administrative and service activities of the Bureau and the radiation physics laboratory. These buildings were originally scheduled for occupancy in the fall of 1964, but it now appears that occupancy will begin in January 1965 and will be completed by April 1965. Construction of a Nuclear Reactor Building should also be completed by June 1965.

On August 21, 1963, a contract was awarded, with a contemplated completion date in November 1965, for the Phase III superstructures for the seven general-purpose laboratory buildings. Work progressed well on these buildings, and it is expected that they will be under roof and enclosed before December 1964.



*Located at Boulder, Colorado

Planning of Phase IV, the special-purpose laboratory buildings, was well under way and bids were expected to be obtained and a contract placed for these buildings in the late spring of 1965.

Also in the planning stage was a major building to house the expanding activities of the Radio Standards Laboratory at Boulder, Colo.

At the end of the year, the full-time permanent staff of the Bureau totalled 3,905 persons. Of this number 2,675 were employed in the Washington laboratories, and most of the remainder were attached to the Bureau's laboratories in Boulder, Colo. Additional information concerning the staff can be found in appendix 3.2 (p. 236).

Funds obligated by NBS during fiscal year 1964 totalled $99,315,000 which included $43,272,000 for facilities. The total available for operation of the Bureau's technical programs amounted to $47,893,000, of which $30,009,000 came from direct appropriations to the Bureau and $17,884,000 from other Government agencies and private sources. In addition, calibrations, testing, information services, and other reimbursable technical services amounted to $7,341,000. A more complete presentation of financial data can be found in appendix 3.3 (p. 236).

TECHNICAL INFORMATION

To be fully useful to the Nation, the large volume of scientific and technical information that is continually being developed at NBS must flow as rapidly as possible into science, industry, and commerce. Several channels were utilized to maintain this flow; they included seven series of nonperiodical publications, papers by NBS scientists in the Bureau's periodicals as well as in professional journals, participation in exhibits, and the production and dissemination of motion pictures.

During the year NBS publications totalled 1,112 formally published papers and documents. In addition, some 445 classified and unclassified reports were issued to other Government agencies. A list of publications for the fiscal year is given in appendix 3.7 (p. 246).

Of the formal publications, 217 appeared in the *Journal of Research,* and 685 in the journals of professional and scientific societies. Also, 121 summary articles were presented in the Bureau's monthly *Technical News Bulletin.* A third periodical, the monthly *Central Radio Propagation Laboratory Ionospheric Predictions,* presented radio propagation data needed for determining the best radio frequencies for use in long-range radio communications.

In the nonperiodical series, 89 documents were published: 9 in the Monograph series, 9 in the Handbook series, 1 in the Applied Mathematics series, 10 in the Miscellaneous Publication series, 46 in the Technical Note series, 9 Commercial Standards, and 5 Simplified Practice Recommendations.

The Clearinghouse for Federal Scientific and Technical Information (p. 167) processed 30,000 titles into its collection of reports, bibliographic information, and translations. These were made available to the public and announced in U.S. Government Research Reports and Technical Translations, both published semimonthly.

An outstanding publication of the year was the *Handbook of Mathematical Functions—With Formulas, Graphs, and Tables* (NBS Applied Mathematics Series 55). This comprehensive reference work, the product of seven years' effort, brings together, under one cover for the first time, text, tables, graphs, and even bibliographies of the more important mathematical functions. It includes all functions normally needed by teachers, students, mathematicians, engineers, physicists, chemists, biologists, bio-

Aerial view showing the various stages of building construction at the new NBS Gaithersburg facilities. At the top center is the administration building surrounded by the seven general purpose laboratories. The Engineering Laboratory is shown at the center left, the Radiation Physics Laboratory at center right, and the Research Reactor Laboratory at lower right. (See page 25)

chemists, and medical researchers. The Handbook was compiled with financial support from the National Science Foundation and technical advice from a committee of the Mathematics Division of the National Research Council. It has already gone into its second printing, and portions of the book are now being reprinted by private publishers.

Another major publication was *Methods for the Dynamic Calibration of Pressure Transducers* (NBS Mono. 67). The practicing engineer, faced with the problem of making dynamic measurements and calculations of the rapidly changing pressures in missiles and space vehicles, should have at hand and be familiar with a large quantity of very precise information. Monograph 67 provides this information, for the first time in a single reference source.

Experimental Statistics (NBS Handbook 91), also issued this past year, is a one-volume collection of statistical procedures useful in the design, development, and testing of materials; the evaluation of equipment performance; and the conduct and interpretation of scientific experiments. This Handbook is for the user with an engineering background who occasionally needs to use statistical techniques, but who does not have the time or inclination to become an expert on statistical theory or methodology. Originally developed for the Army and issued by that service in a series of pamphlets, *Experimental Statistics* has now been made available to other groups concerned with research and development.

Among other nonperiodical publications of the year were *Compilation of the Melting Points of the Metal Oxides* (NBS Mono. 68), *The NBS Standard Hygrometer* (NBS Mono. 73), *Tabulation of Data on Receiving Tubes* (NBS Handb. 83), *Tensile Impact Properties of Selected Materials from 20 to 300 °K.* (NBS Mono. 63), *Inspection of Processed Photographic Record Films for Aging Blemishes* (NBS Handb. 96), and *Creep and Drying Shrinkage of Lightweight and Normal Weight Concretes* (NBS Mono. 74).

During the year, the Bureau participated in 13 exhibits, including those of the National Academy of Sciences; Standards Engineers Society; Color Marketing Group; Instrument Society of America; and Howard University Engineers Day. An interest-arousing new exhibit was an audience-participation model of FIST (*F*ault *I*solation by *S*emi-Automatic *T*echniques) (see p. 192).

NBS films continued to convey Bureau information to an impressive number of people. Prints were loaned for 4,559 showings last year to an estimated total of nearly one-half million persons. This figure includes formal screenings of the films on educational television, but does not include other uses of the films on television channels. Released during the year was *The Calibration of the Platinum Resistance Thermometer,* a film directed primarily toward standards and calibration laboratory supervisors and their staffs. It is also of interest to other industrial and science groups concerned with precision measurement. The NBS film, *Scatter Radar: Space Research from* *the Ground*, produced in 1963, this year won third prize in the popular science category at the Festival of Technical-Scientific Films in Budapest, Hungary, and was selected for entry in the Second International Congress of Scientific and Medical Films, held in Bologna, Italy.

2. HIGHLIGHTS OF THE TECHNICAL PROGRAM

The Bureau's technical program is carried out through organizational units within the four Institutes. These are shown in appendix 3.1 in numerical order within each Institute. A review of selected research and development programs is presented in this section under headings corresponding generally to these organizational units.

2.1. INSTITUTE FOR BASIC STANDARDS

The Institute for Basic Standards has primary responsibility for those central national service provided by NBS which are related to standards for physical measurement and to critically evaluated standard reference data on the properties of matter and materials. It shares joint responsibility with the other Institutes for those central national services of NBS which are related to standard reference materials technological information, acquisition of reference data on properties of matter and materials, and consulting and advisory services.

These responsibilities are met by means of a scientific and technical program which has essentially three missions: (a) the Standards Mission, (b) the Reference Information Mission, and (c) the Consultative and Advisory Services Mission, supported by a fourth, (d) Internal Support Mission.

The Standards Mission is *To provide the central basis within the United States for a complete, consistent, stable system of physical measurement properly coordinated with the systems of other nations.*

The measurement system refers to the group of physical quantities, basic and derived, whose units of measure are usually defined on the basis of international agreement and to the relationships among them which must be consistent with the system of physical equations used in their definition. These physical quantities of measurement are considered distinct from properties of matter and material which are essentially relationships between physical quantities characterized by a particular kind and state of matter. Measurements in terms of these quantities provide the basis for scientific communication and for the technological operation of our mass production industry.

In fulfilling its measurement responsibility, the Institute for Basic Standards develops and maintains the national standards and coordinates them with other nations. To disseminate the measurement system it calibrates the master standards for other standards laboratories and measurement centers, circulates transfer standards, provides standard reference materials to permit self-calibration, broadcasts standard frequencies, and provides other essential services leading to accurate and uniform physical measurement throughout the nation.

To keep pace with the most advanced requirements of science and technology, it carries out research and development on improved standards, measurement techniques, and instrumentation.

Strongly supplementing these activities are the Institute's projects relating to the fundamental physical constants. These constants are, in effect, a set of universally accessible standards. For example, one can in principle calibrate a thermometer with the aid of the Boltzman constant; an ammeter with the aid of the Faraday constant; or a magnetometer against the known value of the gyromagnetic ratio of the proton. Equally important, an analysis of the values obtained for the same constant by different methods, and of the relations between different constants, affords a sensitive check on the consistency and stability of the measurement system itself. Therefore the IBS keeps abreast of the measurements of fundamental constants made by other laboratories; and it makes determinations of them itself, especially when advances in technique, promising improved precision, have made a redetermination valuable.

Proper dissemination of the measurement system also involves the dissemination of certain technological information related to techniques for measurement of physical quantities in typical engineering or production process measurements. IBS work in this area is closely coordinated with the work of the Institute of Applied Technology.

The Reference Information Mission is *To provide the central basis for a national system of critically evaluated standard reference data covering the properties of electromagnetic radiation, subatomic particles, nuclides, atoms, molecules, bulk matter, and highly characterized materials, including the important parameters characterizing their mutual interactions.*

In this mission is included the administration of the National Standard Reference Data System (NSRDS), a responsibility assigned to the National Bureau of Standards during the past year by the Federal Council for Science and Technology. The NSRDS is the first organization to plan and coordinate standard reference data on a continuing and national basis. Its scope is expected to embrace the following program areas; nuclear physics, atomic and molecular physics, solid-state physics, thermodynamics and transport properties, chemical kinetics, colloid and surface properties, and mechanical properties, with others to be added as the need arises.

In establishing and maintaining the NSRDS, the Institute for Basic Standards undertakes the following specific responsibilities:

(a) To develop a central system for the organization of the body of standard reference data into a meaningful and useful pattern.

(b) To coordinate existing groups or regional centers and to establish new groups or centers, both in and out of NBS, for the collection, analysis, and critical evaluation of existing data.

(c) To establish a system of national committees relative to selected subject-matter areas for expert advice and consultation on needs for data, priorities for acquisition, location of proper talent or facilities for data acquisition or analysis, and general guidance for the national system.

(d) To establish and operate a central coordinating office for activities relating to the NSRDS.

(e) To establish and operate a National Reference Data Center for collection and dissemination of evaluated data, including research on data-processing problems and procedures unique to the System.

An important aspect of the accomplishment of the Reference Information Mission is the activities concerned with the development and dissemination of theory and measurement techniques which lead to the general improvement nationally in the ability to determine properties of matter. It is the broad base of technical and scientific competence in the determination of physical and chemical properties and in the analysis and interpretation of measurements involved in these determinations which makes the National Bureau of Standards a laboratory that can accept the responsibility for development of the NSRDS.

The program of acquisition and dissemination of reference information and data is separated into two major areas. The first of these, the determination of the microscopic properties of matter, which includes measurement of parameters that characterize the interaction of elementary units of matter with electromagnetic radiation and with each other, is a primary responsibility of IBS with selected activities in this area performed by other Institutes by agreement. In the other area, i.e., of macroscopic properties of matter, IMR has the primary responsibility. Because of the close interaction with statistical concepts and with the thermodynamic foundation of the temperature scale, IBS assumes responsibility for those macroscopic properties in the general area of thermodynamics and transport phenomena. Electromagnetic and optical properties of certain materials, the measurements of which are most appropriately conducted by elements of the IBS organization which are closely tied to the standards mission, are undertaken by agreement with IMR.

In the area of consulting research and advisory services the staff of NBS and, within its field of competence, that of IBS makes its principal direct contact with the scientific public. The activities involved here are almost entirely confined to the individual interactions between NBS staff members and individuals or small groups in outside organizations.

A major implied responsibility resulting from this mission is that IBS and the other Institutes incorporate in their program a continuous study and evaluation of new scientific and technological discoveries to provide part of the basis for modifications of Institute programs, so that they can meet the impact of assimilation of these discoveries into current scientific and industrial practice.

Also ranged under this mission are extensive projects relating to the preparation of mathematical tables.

Activities under the internal support mission are grouped under four headings:

(a) *General research.* Experimental or theoretical research on broader physical problems whose results are needed as a basis for work elsewhere in the Bureau.

(b) *Computing center.* Operation of a center for research and service whose aim is to promote effective utilization of data processing facilities within the Federal Government.

(c) *Technical services.* Principally, consultation and collaboration on problems requiring statistical analysis and other techniques of applied mathematics.

(d) *Radiation sources.* Design, construction, operation, and use-planning of the NBS linear accelerator ("Linac") and auxiliary equipment, Synchrotron, and Van de Graaf generators.

In subject areas where the missions of more than one Institute are involved, the Institute for Basic Standards participates in inter-institute collaborative programs. Certain properties of bulk matter, for example, are of interest to both IBS and the Institute for Materials Research, and research programs on these properties are being carried out under a joint arrangement of the two Institutes.

2.1.1. THE NATIONAL STANDARD REFERENCE DATA SYSTEM

Last year the President's Office of Science and Technology established the National Standard Reference Data System (NSRDS) with the general objective of providing critically evaluated quantitative data in the physical sciences to the technical community of the United States. The Bureau was assigned the administration of the system, which will coordinate and integrate a large part of the present data compilation and evaluation activities of a number of Government agencies. To direct the program, an Office of Standard Reference Data (OSRD) was established within the Bureau's Institute for Basic Standards.

The specific responsibilities assigned by the President's Office are (1) promotion of the general objective; (2) coordination of standard reference data activities of NBS and other Government agencies; (3) operation of a National Standard Reference Data Center at NBS; and (4) establishment of standards of quality and methodology.

The administrative plan for the NSRDS calls for decentralized data gathering and evaluating by many individual scientists and technical groups. Their advice and active assistance will be utilized in implementing the program, which is expected to have an ever-changing emphasis as the requirements change over the years.

The NSRDS is concerned with the production of compilations of critically evaluated data and the dissemination of these data. The program includes the collection and evaluation of data from the literature; the preparation of critical reviews of the state of quantitative knowledge in a particular technical field; and the computation of useful functions that are derived from standard reference data or that are used in the interpretation of quantitative experiments. These products may appear in a variety of forms, such as monographs, decks of data-processing cards, loose-leaf sheets, computer programs, or computer tapes.

For the initial phase of the program, the following technical areas have been selected: (1) nuclear data; (2) atomic and molecular data; (3) solid-state data; (4) thermodynamic and transport data; (5) chemical kinetics; (6) colloid and surface properties; and (7) mechanical properties of materials. In each of these areas a survey of existing activities was made. Competent technical groups will undertake the high priority activities. In some cases these groups are within NBS; in others, they are in academic, industrial, or Government laboratories.

To make NSRDS products conveniently accessible, a variety of information services will be offered. The National Standard Reference Data Center will ultimately house a complete collection of all compilations of critically evaluated data produced throughout the world, adequately indexed and stored for rapid retrieval.

The Center will provide a centralized source for the output of all groups designated as components of the NSRDS; however, localized distribution may be accomplished through existing mechanisms. A periodical publication is being planned to describe the contents of the data file, current projects underway, and other relevant information. A library of computer tapes will be maintained and printouts of stored or computed data will be prepared on request. Replies to inquiries will provide either the best available data or a referral to the best available source of data.

Special problems connected with the collection and evaluation of quantitative data are being encountered. Attention is being given to the formulation of these problems, so that they may be solved by means of new data-processing techniques now available within the Bureau and from outside organizations.

Status of Technical Area Programs

(1) *Nuclear Data.* Consultations with nuclear physicists and compilers of nuclear data indicate that compilation and evaluation activities covering various types of nuclear data are perhaps more extensive than in any other field. At present, the major requirements in this area are being adequately met. However, new techniques are rapidly increasing the rate of data production. Improved efficiency and dissemination of data can probably be achieved by sharing literature-scanning and indexing tasks among compilers or by persuading authors to perform part of the job; by reaching agreement on a common format and on methods of presentation among the various groups compiling and using neutron cross-section data; and by providing a mechanism for publication and distribution of a number of existing special-purpose compilations which have not yet been published in the open literature.

(2) *Atomic and Molecular Data.* Some well-established activities in the field of atomic and molecular data have demonstrated their worth to the technical community. NBS work in this field includes data compilations on atomic energy levels, atomic transition probabilities, the interaction of electromagnetic radiation with matter, and microwave spectra, and a literature survey of existing data on mass spectroscopy.

A contract was negotiated with the American Society for Testing and Materials for a joint program on the collection and evaluation of the infrared spectra collections of various Government laboratories. Discussions were held with users and producers of infrared spectral data in the Food and Drug Administration, National Institutes of Health, Bureau of Customs, and the Army Chemical Corps. As a result, over 700 spectra of pure pharmaceutical compounds are being readied for microfilming and evaluation.

(3) *Solid-State Data.* The dynamic growth of solid-state physics during the past 15 years has been surveyed and evaluated in a compilation entitled "Solid-State Physics, Advances in Research and Applications," but a corresponding effort has not been made to evaluate and compile the available quantitative data. A survey of needs and priorities by a panel of specialists is planned prior to establishing a data compilation program. A cooperative relationship was established with the Johns Hopkins University group, producing the compilation "Crystal Data," and other cooperative programs are being explored.

(4) *Thermodynamic and Transport Properties.* A survey of existing programs indicates a need for expansion to provide the required coverage. Progress to date includes staffing of existing compilation centers, identification of the gaps in technical coverage, and establishment of a priority list of needed activities. In addition, cooperative programs were established with the Manufacturing Chemists Association and the American Institute of Chemical Engineers, and discussions regarding a joint project were held with representatives of the American Petroleum Institute.

(5) *Chemical Kinetics.* From a survey of this field, it was concluded that critical reviews of a number of special areas are needed. This conclusion was confirmed by an NAS–NRC panel whose members indicated that they would either prepare critical reviews themselves or would arrange for appropriate specialists to do so. Consequently, a series of monographs is now planned. Thus far, specific proposals have been received for four titles in the series from scientists who wish to take part in the program.

As an aid in the preparation of the reviews, a literature center was established at NBS to minimize the need for repetitive searching of the literature to locate relevant material.

(6) *Colloid and Surface Properties.* Shortly before the establishment of the NSRDS, a subcommittee of the NAS–NRC Committee on Colloid and Surface Chemistry, under the chairmanship of Dr. H. van Olphen of the Shell Development Company in Houston, Tex., began to plan an extensive program for data evaluation and compilation. The Office of Standard Reference Data entered into a cooperative endeavor with the subcommittee to complete the plans and to make arrangements for the preparation of appropriate tables and reviews. Several proposals were received for support of specific projects within the program.

(7) *Mechanical Properties of Materials.* A survey of this field identified areas in which compilations and reviews would be valuable. The tentative program outline will be discussed with a group of specialists to develop final plans.

Relationships With Other Government Agencies. Discussions were held with representatives of the Department of Defense (DOD), the Atomic Energy Commission, National Aeronautics and Space Administration, National Science Foundation, and other agencies. These discussions explored plans and existing programs, possible joint projects, and relationships between the NBS program and existing data-compilation projects. Criteria for designation of data centers as components of the NSRDS were developed and agreement was reached with the DOD Director of Technical Information on the selection of several DOD data centers.

During the year, two program reviews were presented to the Committee on Scientific and Technical Information of the Federal Council for Science and Technology (FCST). The formal action to establish the NSRDS originated with a recommendation of this committee, and the action taken by the FCST directs NBS to report periodically on the plans and progress of the program.

2.1.2. APPLIED MATHEMATICS

The Bureau's applied mathematics facility performs research and provides assistance in the application of mathematical and statistical techniques. Its services are available to other Government agencies as well as to the Bureau's staff. The facility uses modern computing equipment in support of the program.

During the past year the Bureau continued research in statistical and numerical analysis, mathematical physics, and operations research—all of which are fundamental to its mission. Extensive assistance was rendered in these areas and in digital computation. In the latter field, emphasis was placed on problem formulation and analysis in order to select and develop appropriate numerical methods. Automatic high-speed computing machines were utilized when appropriate. The mathematical program was devoted both to problems in engineering and the physical sciences and to government problems of business management and operation, sometimes called data-processing problems. Progress continued in exploring the use of modern digital computers in the mechanical translation of scientific publications. A rapid translation method is urgently needed.

The Bureau's program in applied mathematics was strengthened by the active interest and support of other Government agencies. The U.S. Army Research Office, the National Aeronautics and Space Administration, and the Office of Naval Research supported basic and applied research in numerical analysis and mathematical physics. The National Institutes of Health and the National Science Foundation supported research in pictorial data processing and artificial intelligence. The study of mechanical translation of scientific publications was jointly supported by the U.S. Army Signal Corps and the U.S. Army Research Office.

The Bureau's applied mathematics program is conducted at both the Washington and Boulder facilities. The following activities were carried out in the Washington facilities, except for the last two items, as noted.

Numerical Analysis. Research in numerical analysis is of vital importance in contributing to the effective use of electronic digital computing equipment, both in applying such equipment to scientific and engineering problems and in utilizing it as an aid to decision-making by management. To be effective, research in this area must be based on comprehensive knowledge of many underlying mathematical subjects. The numerical analysis program is thus carried out by mathematicians who are experts in many fields of mathematical analysis.

Asymptotic Expansions and Analysis. Error bounds for asymptotic expansions of the solutions of ordinary differential equations were determined and the results applied to the special functions of mathematical physics. The entire solutions of functional equations were studied.

Eigenvalue Determination. Eigenvalues were obtained for the Shrödinger equation with a Heitler-London potential. The computations were carried out on the Bureau's electronic computer to check the accuracy of the second-order-WKB approximations to this operator. This work was done in cooperation with and on the suggestion of the Physics Department of Georgetown University.

Similar work done in the theory of relaxation of a Lorentz gas led to a typical but unsolved eigenvalue problem.

Systematic determinations of eigenvalues of different operators were carried out by lower-bound techniques combined with Rayleigh-Ritz upper bounds. These techniques are of fairly recent origin and prove to be by far the most promising means of finding eigenvalues of ordinary and partial differential operators when other methods fail.

Quadrature and Interpolation. Methods for the evaluation of multiple integrals by a modified Monte Carlo procedure and by number-theoretical procedures were investigated, and theoretical error bounds were established and then verified by computational experiments.

Linear Algebra, Matrix Theory, Group Theory, and Number Theory. Iterative sequences of vectors converging to the dominant eigenvalue of a positive matrix were studied. The structure of various discrete matrix groups of importance in the theory of automorphic functions was determined. Multipliers of difference sets were investigated and new classes of multipliers were found. New classes of Hadamard matrices were constructed. A proof was given of the fundamental theorem that a bounded automorphic form of dimension zero on a function group is constant. The tabulation of basic number theoretic tables continued.

Machine Translation. The soundness of the "predictive analysis" scheme initiated at the Bureau was demonstrated through on open test of the method on Russian sentences composed of words formed from the limited number of stems presently stored in the computer's glossary.

Pictorial Data Processing and Artificial Intelligence. The National Science Foundation sponsored an investigation of the techniques of syntax direction for interpreting syntactically described information sources. The technique developed for natural language sources was extended to include schematic pictures. A computer algorithm capable of generating and analyzing a large body of English sentences which describe pictorial images was developed.

The National Institutes of Health sponsored research on computer techniques for processing biological patterns. Photomicrographs of brain tissue are to be automatically processed in order to study, by simulation, the specific future machines for implementing such processing.

Mathematical Tables. The *Handbook of Mathematical Functions* was issued as Applied Mathematics Series 55. This volume extends the work of past authors by increasing the number of functions covered, by presenting more extensive numerical tables, and by giving a larger collection of mathematical properties of the tabulated functions. Preparations are under way for publication of Tables of Power Points of Analysis of Variance Tests and Tables of the Sievert Integral.

Digital Computation. The Bureau's computation facilities were improved by replacing the IBM 7090 computer with an IBM 7094 computer. The arrangements with the Harry Diamond Laboratories, U.S. Army, for the operation of an IMB 1410 were continued. Both scientific and data processing problems continue to require the extensive use of these facilities.

The service role of the Bureau's Computation Laboratory to other Government agencies was recognized and formalized, on an experimental basis, by a Bureau of the Budget Bulletin designating the Computation Laboratory as a Federal Service Center for the Washington, D.C., area. In addition, a Sharing Exchange was established to provide information on the availability of computing facilities within Government to interested agencies.

Approximately one-third of the computing services performed during the year were on problems originating within the Bureau. On a continuing basis, important computations were performed on problems in the thermal dissociation of molecules, diffusion and reactions in gases, polymers, multilayer adsorption studies, neutron cross sections, equation of state, and interaction radiation. While new tasks were continually originating within the technical areas of the Bureau, they were generally included as part of the continuing work. However, closer ties to the civilian economy and engineering needs were reflected in computations for a standards study of the lumber-industry.

The remaining two-thirds of the computing services performed were for 31 other departments, agencies, and offices of the Government. In addition to agencies regularly using these facilities, computations were performed for various segments of the Department of Health, Education, and Welfare, the Office of Business Economics, the Bureau of International Commerce, the Institute of Defense Analysis, the Defense Supply Agency, the Armed Forces Institute of Pathology, and the Geological Survey. In addition to the computational services for these agencies, theoretical analysis on systems of integro-differential equations and interplanetary and orbital calculations were performed. Discussions on systems of differential equations describing the flow of an electrical impulse in a neuron were also initiated. Among the many problems studied in the area of data processing are preparation of tables relating to the status and career orientations of college faculties, analysis of health examination data, and study of the requirements and feasibility of supersonic transports.

In cooperation with the National Institutes of Health, an evaluation was made of the organization of their computational facilities and their relation to the scienific and administrative needs of the different Institutes.

Research continues in the field of automatic programming and artificial programmer-oriented computer languages. Test problems were constructed which are used to measure and compare the efficiency of machines, programming languages, and compilers. One such problem, the calculation of eigenvectors and eigenvalues, was run under a variety of conditions which included different machines, FAP coding, FORTRAN coding, and single and double precision.

Statistical Engineering. The principal function of the Bureau's 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 help the Bureau's scientists and technicians conduct their research, development, and testing programs so as to reach conclusions of desired scope and reliability at the lowest possible cost. Effective use must be made of modern probability and statistical methods in an attempt to offset limitations of funds, equipment, materials, and personnel. Extensive services were rendered ranging from short informal conferences to active collaboration with project leaders for periods of several months.

Research and Development. The Bureau conducts a continuing program of research in mathematical statistics and probability, to maintain and increase the effectiveness of statistical services. Continued investigation of Youden's rank sum test for outliers led to the development of generalized applications for the test. Tables of one-sided percentage points for the test were prepared and published, so that both two-sided and one-sided tables are now available.

The best least-squares method for estimating the slope of a straight line through the origin is well known, and is readily applied when the correct weights are known. In practice, however, the correct weights are usually known only approximately. The Bureau has recently completed a study of the relative advantages and disadvantages of the most important weighted estimates if they are used when the correct weights are not known. The results of this study will guide data analysts in choosing the best estimator in a particular situation.

The Bureau conducted a numerical investigation of the properties of a statistical estimation procedure in which measurements are taken until two identical readings have been obtained. This procedure for making determinations based on duplication of readings occurred as part of a tentative calibration method published by the American Society for Testing Materials.

Cooperative Activities. The major cooperative activities in statistical engineering were related to the Bureau's calibration programs. Methods for representing the precision and accuracy of measurement processes and statistical designs for eliminating the effect of environmental factors are the subject of most of this work.

A good example of this collaborative activity has been with the engineering mechanics laboratories (p. 61). As a result of this collaboration, a new form of report of calibration has been adopted for the calibration of proving rings. The new report, which replaces the type in use since 1948, includes a table of load values and detailed information on precision and accuracy of the calibration.

Another example is collaboration with the Bureau's radioactivity laboratory on studies of the calibration of radiation standards. These studies included, in addition to the problems of design for the multiple comparisons among the standards and the unknowns, the concomitant investigation of the effect of experimental factors, such as position and time trend, on the precision and accuracy of the results.

The Bureau has been active for a number of years in the statistical aspects of measurement and reporting of the precision and accuracy of measurement processes. In addition to performing work directly for other NBS laboratories, the Statistical Engineering Section has cooperated with technical and standardization associations and with other persons active in the field of precision measurement. An opportunity for more extensive personal association with personnel from measurement laboratories interested in the area of precision and accuracy in measurement and calibration was provided by a week-long seminar conducted by members of the section and attended by 14 meteorologists from industrial and governmental laboratories.

Members of the section are active on committees of a number of professional and technical societies including committees of the American Society for Testing Materials, the American Standards Association, and the American Society of Tool and Manufacturing Engineers. An important example of this work was assistance to the International Atomic Energy Agency in the planning of interlaboratory tests for establishment of standard samples for uranium and for trace elements associated with uranium.

Operations Research. General areas of investigation during the past year included linear programming and its extensions, graph theory, game theory, stochastic processes, and mathematical models of distribution networks.

Significant progress in graph theory and related optimization problems continued, under the sponsorship of the Army Research Office. Past work on finding maximum sets of isolated edges in linear graphs was both implemented computationally and extended theoretically to the problem of finding maximum-weight sets of (weighted) edges with a quota on the number of chosen edges allowed at each node. An efficient method was developed for encoding graphs without circuits, a topic arising in connection with storage and retrieval of chemical structure information. The convex hull of the incidence vectors describing the spanning trees of a graph was determined, as were several related convex hulls. A characterization was found for the possible node-degrees of a graph all of whose cut-sets of edges contain at least a prescribed number of edges.

A variety of investigations pertinent to postal mechanization were carried out for the Post Office Department. Some involved cost-benefit analysis of proposed mail-sorting subsystems and of alternative approaches to the encoding of addresses for subsequent machine use. Others dealt with stochastic processes in certain mail-handling operations. Work was completed on a major exploration of mathematical methods and concepts relevant to the "warehouse" problem of locating a single processing facility (here, a large mechanized sorting installation) so as to minimize the total cost of transportation between it and its customers. Results included analytical solution of idealized representative cases, development and testing (on Chicago data) of a computer code for more realistic cases, and a clarification of several mathematical problems arising out of the asymmetry of travel costs between a pair of points.

Demand for consulting and advisory services in operations research continued to increase. There was particular emphasis on such areas as industrial modeling and economic analyses, with work in these respective areas being performed for and with the program in textile technology and the Commerce Department's supersonic transport project. A promising start was made on developing (for the Veterans Administration) computer procedures for facilitating hospital floor layout, with emphasis on translating into specific algorithms the architect's assessment of the relative importance of proximity for different types of functional units.

Mathematical Physics. The function of the program in mathematical physics is to aid and advice the Bureau's professional staff on the application of mathematical techniques to the solution of problems in engineering and the physical sciences, and to conduct research in areas pertinent to this function. Studies were conducted on the formulation of realistic constitutive equations for nonlinear viscoelastic materials and fluids, the determination of bounds on the solutions of problems in elastic materials, partial differential operators of hyperbolic type which satisfy Huygens' principle, the behavior of solutions of nonlinear differential equations occurring in oscillation problems, and the bending of elastic plates under point supports.

Theory of Satellite Orbits. Research in this area of great importance to the National space program has been sponsored for several years by the National Aeronautics and Space Administration. The principal problem is how best to account for deviation of the earth's shape from that of a sphere. A promising method based on spheroidal coordinates has been developed. Current efforts are concerned with corrections for the finer details of the earth's shape, such as equatorial asymmetry. Work in progress on the effects of a constant force on such an orbit should have application to the problem of radiation pressure.

A preliminary study has been made of the feasibility of measuring or compensating the drag on a manned satellite. Information obtained in this manner would be helpful in determining atmospheric densities and the figure of the earth, and would eventually be useful in providing experience in the design and operation of a zero-G laboratory.

Research in Plasma Physics. Studies in the dynamics of plasms were conducted essentially in two areas during the last year: interaction of plasmas with a magnetic field, and statistical dynamics of plasmas with application to propulsion. The first research program was part of a Bureau-wide effort in this field, and was concerned with the transport properties of a plasma interacting with a magnetic field. As part of this project, a seminar was conducted on the theory of plasma dynamics. The second research program was started two years ago at the request of the National Aeronautics and Space Administration, and centers about the kinetic equations of plasma theory, plasma oscillations, and the bearing of these on the application of plasmas for space propulsion. Numerical solution of some of the simpler nonlinear problems is under way.

Whisker Growth. A theoretical study was started on the growth of mercury or potassium whiskers in vapor atmospheres (see p. 147). The problem is nonlinear and requires an electronic computer for its solution. The mathematical formulation in terms of two simultaneous integral equations turned out to be most amenable to numerical computation. This study is expected to give information on the validity of the screw-dislocation theory.

Mathematics Group at the Boulder Laboratories.* The workload of the Boulder, Colo., computation facility increased with greater utilization by the Bureau of Reclamation, the U.S. Air Defense Command, the Geological Survey, industrial laboratories, universities, and the National Center for Atmospheric Research. Effectiveness of the computer system is broadened through the possibility of using a powerful new executive program and through the increased availability of double-precision computer programs. The computer has been programmed to write a magnetic tape suitable for input to a new high-speed plotting machine which prepares point or symbol plots and contour line drawings.

Other technical computer programs were written to compute the error function of a complex variable, Airy functions of a complex argument, the near-zone electromagnetic field of a quarter-wavelength dipole antenna, the capacitance of a pair of hemispheres, the solution of a system of three simultaneous first-order nonlinear differential equations for electromagnetic phase corrections, and the values of certain integrals and derivatives connected with the absorption of electron energy in the atmosphere.

Studies of two-phase fluid flow continued with the numerical calculation of

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*This activity is a part of the Manager's Office, Boulder Laboratories.

neutral stability curves in a vertical pipe and the preliminary analysis of annular flow in a horizontal pipe. Numerical tests were made on a model for transient two-phase flow in a pipe with heat exchange.

A method for the computation of the error function of a complex variable was derived and published. This method was applied to the computation of the response to a swept frequency input of the general electrical circuit containing resistance, inductance, and capacitance.

A method and programs were prepared for the application of a large computer to billing procedures in the Boulder printshop and drafting rooms.

Statistical Studies at the Boulder Laboratories.* Four projects in or related to mathematical statistics were completed, and several others continued or initiated. These programs are directed primarily towards the planning or data analysis of investigations in radio propagation and radio standards, but usually have more general applicability. Completed were papers demonstrating the insensitivity (within limits) of the cost of heirarchies of calibration systems to accuracy ratios between echelons, papers on detailed comparison of several methods of estimating parameters of a generalization of the Poisson distribution, on approximating distributions of quadratic forms in normal random variables, and on statistical inference for Rayleigh distributions.

Studies continued on precision of estimation of variance components from time series, especially for atomic frequency standards; robust estimation of medians of symmetrical distributions, with applications to standards; and tabulation of the distribution functions of the complete range of stable distributions. A study of the robust estimation of percentiles from small samples was initiated as the result of interest by radio propagation scientists.

2.1.3. ELECTRICITY

The Bureau's work in electricity is primarily the development, improvement, and dissemination of the standards of measurement for electrical quantities; and procedures and techniques for very accurate electrical measurements, such as are needed in studying dielectric and magnetic properties of matter. Electrical standards must be established that are constant over long periods of time, uniform throughout the nation, and compatible with other standards used throughout the world. Measurements of electrical quantities directly in terms of length, mass, and time ("absolute measurements") are extremely difficult and are made only in the realization and confirmation of electrical standards of resistance, capacitance, inductance, and voltage; calibration work is done by comparison with these electrical standards.

Electrical Units.

Current. Repeated determinations of proton-precession frequency and of rubidium Zeeman-transition frequency are necessary to the Bureau's continuing surveillance of the constancy of the *legal* volt and ohm. The deter-

*This activity is a part of the Manager's Office, Boulder Laboratories.

minations are made in a 0.0012-tesla field stated in terms of the NBS ampere, which is defined as the ratio of the NBS volt to the NBS ohm. Analysis of such measurements over a four-year period indicated that the NBS ampere has remained constant to about one part in a million. This uncertainty (1 ppm) results essentially from limitations in measuring the dimensions of the solenoid in which the precession-frequency measurements are made.

The possibility of monitoring and correcting variations in the earth's field at the solenoid was investigated using a self-oscillating rubidium magnetometer in a secondary Helmholtz-coil system, phase-locked to a standard frequency and supplying a correction signal to the principal Helmholtz-coil system surrounding the solenoid. This "dynamic shielding" system was successfully operated, but cannot be used in the Bureau's present location because of the differences in field conditions at the sensing element and at the solenoid.

Capacitance. A new determination of the unit of capacitance in terms of a gage-bar assembly checked within 1.5 ppm of the unit maintained in terms of a group of standards. Dr. Helmut Hoyer of Physikalisch-Technische Bundesanstalt in Braunschweig, Germany, who expects to build a computable cross-capacitor in his laboratory, assisted in this year's determination.

Parts for an improved calculable capacitor were constructed in the NBS instrument shop and assembly was begun. A capacitance-probe gaging technique was developed that permitted the individual electrodes to be lapped within a 10-microinch tolerance. It is hoped that uncertainties in the determination of the unit can be reduced to a few parts in 10^8—exclusive of the speed-of-light uncertainty.

Standards.

Stable Capacitance Standards. A group of 10-picofarad (pf) capacitance standards with fused-silica dielectric was built. The design and mounting used were those of a previous standard modified in an attempt to eliminate sensitivity to voltage and shock. Measurements on the new standards indicated that changes with voltage are less than 1×10^{-8} for applied voltages up to 200 volts (V), and shock sensitivity is low. No change was detectable following an axial or radial drop of 15 cm to a hard wood surface. Examination of stability with time and under more severe shock conditions (i.e., shipment by parcel post) will show whether standards of this type can be used in international comparisons of the unit capacitance.

A new three-terminal capacitor was designed that has a direct capacitance independent of the temperature of two electrodes and thus dependent only on the temperature of the third, which can be made of fused silica to give an overall temperature coefficient of capacitance of $0.6 \times 10^{-6}/°C$. The value may be adjusted by simple machining operations on the other electrodes, which may be of any stable metal. The design is useful in the range below 10 pf, and a 5-pf capacitor has been built.

Voltage Dependence of Air Capacitors. The Bureau's 1-pf computable capacitor serves as the starting point for assigning values stepwise to other reference standard capacitors. This step-up process requires that the new capacitors be subjected to alternately high and low voltages when bridge measurements are made; thus voltage dependence must be minimum. A

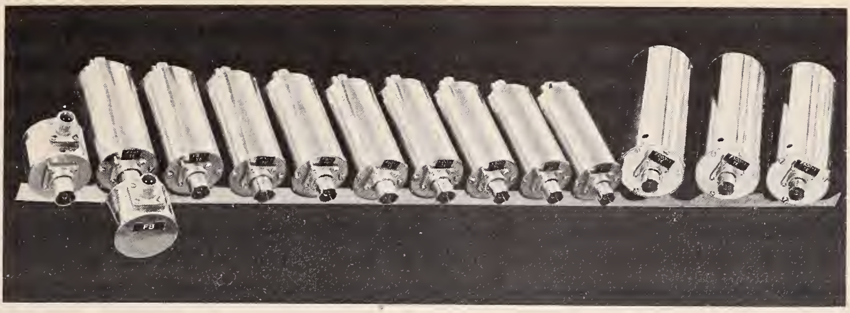
Stable Capacitance Standards. A group of 10-picofarad (pf) capacitors of identical design having a coaxial-cylinder geometry that minimizes changes due to electrostatic forces. A method was developed at NBS for measuring the "absolute" variation of capitance with voltage. With this method, changes amounting to less than 1×10^{-9} can be resolved.

Observed changes amounted to no more than 3×10^{-9} between 10 and 200 V. Two effects were present in the general case—electrode distortion under electrostatic forces, and migration of electrode surface films. Film effects usually amount to 1 part in 10^7 or less; electrode distortion may be neglible or range to several parts in 10^6, depending on geometry and structure.

Galvanic Cell with Thallous Sulfate. The Bureau maintains the unit of electromotive force (emf) for the United States with a group of cadmium sulfate cells. The emf's of these cells are derived from the basic mechanical units of length, mass, and time. During intervals between "absolute" measurements, the emf's of the cadmium sulfate cells are assumed to be invariant with time. However, it is obvious that all of a group of "identical" cells may increase or decrease in emf with time without evident departures from an assigned mean. Another type of standard cell of composition different from the cadmium sulfate cell would therefore be of great value for changes in emf with time in two different systems would not be likely to follow the same pattern.

In an attempt to develop a new type of standard cell, a group of thallous sulfate cells was made with a thallium-amalgam anode and a mercury-mercurous sulfate cathode in a saturated solution of thallous sulfate. At 25 °C this cell has an emf of 1.057511 V and an emf-temperature coefficient of 32×10^{-5} V per degree Celsius. This cell has an emf of approximately 0.04 V higher than that of cadmium sulfate cells and an emf-temperature coefficient nearly seven times that of cadmium sulfate cells; however, it has shown evidence of being sufficiently stable that studies of the ratio of the emf's of thallium sulfate and cadmium sulfate cells may prove valuable in maintaining the national unit of emf. The changes in free energy, heat content, and entropy for the cell reaction were found to be $-204{,}075$ joules per mole (J/mol), 185,661 J/mol, and 61.76 J/°K mol, respectively.

A–C Voltage. A set of twelve thermal voltage converters was designed, constructed, and evaluated. These converters are used in making highly accurate a–c voltage measurements from 1 to 1,000 V by comparison with d–c standards. The frequency responses of these converters were identical within 5 ppm from 20 Hz to 20 kHz, with no evidence of systematic error in the step-up intercomparison process by which the response of each is known in terms of any other one. The a-c–d-c difference of the 1-V converter agreed with that of the basic NBS set of converters to better than 5 ppm. Thus rms



Set of newly designed thermal voltage converters covering the 1 to 1000 volt range. These converters will increase appreciably the accuracy of a-c voltage measurements at audio frequencies. **(See page 46)**

a–c voltage measurements at audio frequencies can be made with a new order of accuracy.

High-Accuracy Current Transformers. Two nearly identical multi-range current transformers for establishing ratios of alternating currents from 0.1 to 50 amperes at audio frequencies were designed and constructed. Their accuracy was determined to a few ppm up to 10 kHz with a 1:1 comparator and a unique intercomparison circuit for stepping up to ratios of 6:1.

Measurement Methods. A passive direct-reading ratio set was built to compare audio frequency admittances. It has a difference range of ± 500 ppm, and a least count of 1 part in 10^9. The new device was built to supplement and perhaps replace an earlier active ratio set that was sensitive to harmonics in the power amplifier and bridge transformers because of nonlinearity in its operational amplifiers. The passive device uses compensated transformer elements rather than operational amplifiers.

A 10:1, three-winding transformer was constructed with a voltage ratio (at 10 kHz) between the secondaries equal, to a high order of accuracy, to the turns ratio. Its residual errors have been determined to better than a part in a million, and it has been used with capacitance ratio techniques to extend the upper frequency limit for the calibration of high precision inductive dividers from 1 to 10 kHz.

A high-voltage pulse generator was built. It consists of a group of pulse-forming networks arranged in a Marx circuit and provides a rectangular output pulse about 12 microseconds in length with an amplitude up to 125 kV. Techniques have been developed for comparing the pulse performance of commercially available voltage dividers with specially constructed reference dividers to an accuracy of the order of 1 percent.

At the request of the Bureau of Naval Weapons, Department of the Navy, the Bureau developed a "Helicopter Battery Service Simulator" for testing helicopter batteries of the silver-zinc and silver-cadmium types under simulated service conditions. The "Simulator" can simultaneously test three batteries by automatically discharging them, first at 300 amperes for 1 second and immediately thereafter at 100 amperes for 9 seconds. Three such sequences are applied within 1 minute. The battery is then charged for 30 minutes at a constant potential. Helicopter batteries are subjected to 20 such discharge-charge cycles per day, five successive days per week. The "Simulator" also provides a continuous record of the battery temperature, charging current, and discharge voltage. A novel voltmeter having a scale of 27 to 28 V was designed and incorporated into the "Simulator" to monitor the voltage during the charging of a battery with an accuracy of 0.1 percent. A zener diode was used for the reference voltage in the voltmeter.

A three-terminal cell, or holder, which permits more accurate dielectric measurements on solid specimens than any previous cell was designed and built. It can be used in liquids with the two-fluid technique which, in conjunction with a bridge of improved sensitivity, permits measurement of the dielectric constant of a disk specimen with an accuracy of 2 or 3 parts in 100,000 at 1,000 Hz without applying contact electrodes to the specimen or knowing the thickness of the specimen or the area of measurement. By measuring a suitable specimen and then measuring this same specimen in other cells, it is possible to determine the effective measuring area of such cells, thus improving the accuracy of the measurements made with them.

The new cell is made in two parts. The spacing between these parts is determined by three gage blocks placed near the edge of the assembly. The cell is so precisely constructed that it can be disassembled and reassembled with a change in capacitance of less than 2 parts in 100,000. Turning the cell upside down does not change the capacitance by as much as 2 parts in 100,000. Five sections have been constructed so that by combining sections, three different effective areas of measurement can be obtained.

The use of the new two-fluid cell and transformer bridge improved the precision of dielectric constant measurements on fused silica and teflon disks by a factor of up to 100 times under restricted conditions of very carefully controlled humidity, temperature, specimen preparation, and positioning of the specimen in the holder. In ideal cases the precision of measurement of ϵ' now is of the order of 50 ppm.

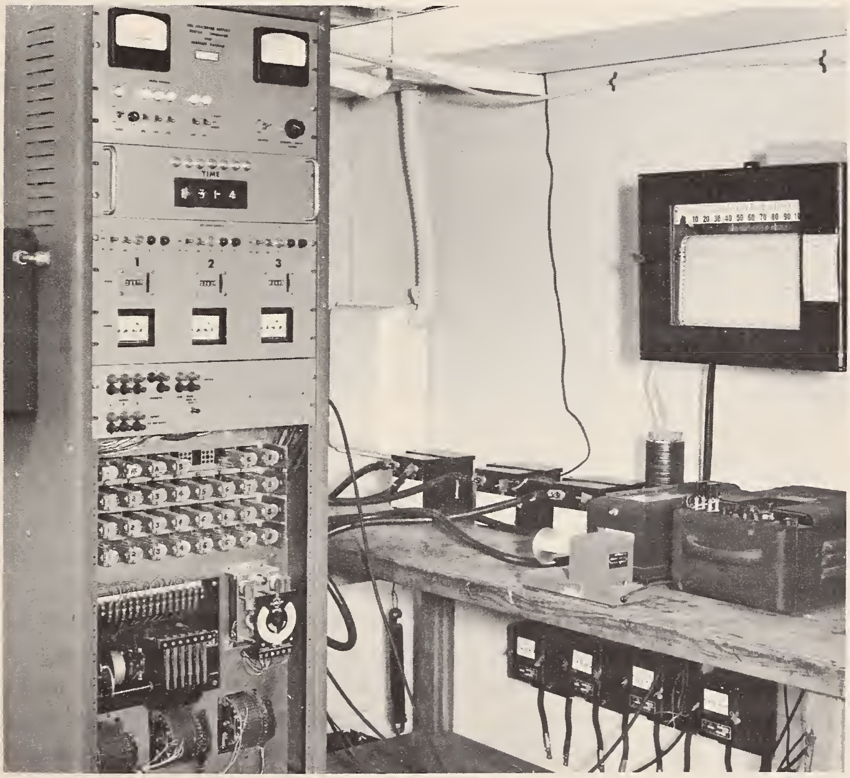
A very simple two-terminal cell was developed for room temperature measurements of a single 1- to 2-gram disk-shaped specimen without contact electrodes over an unusually large range of frequencies—from 10^{-2} to 6×10^{8} Hz. Accuracies of better than ± 1 percent for ϵ' and ± 5 percent for ϵ'' are obtained over the entire frequency range. Calculations have been developed to take into account the air gap, fringing fields, and residual circuit parameters. Several bridges and resonant circuits are used with the cell to cover the frequency range.

A detailed theoretical analysis was completed of the effect on the effective area of a guard ring cell of the guard-gap width, electrode thickness, and dielectric constant of the material in and around the guard gap. The results of the work permit assessment of experimental errors due to the guard gap in precision measurement cells and allow measurements under conditions where these errors are well below the desired 0.1 percent precision limits.

During the work, errors in existing guard-gap theory and application were pointed out and corrected.

Properties of Matter.

Gold Anodes in Electrolysis. As part of a broad investigation of electrolytic processes, gold anodes were studied in aqueous solutions of sulfuric acid free of or containing sodium oxalate. Depending on the magnitude of the electrical potential of the gold, oxygen gas may be evolved at the gold, or a "three-dimensional" oxide film or a "two-dimensional" chemisorbed oxygen film may be produced on the gold. An elipsometer was used to ascertain changes in the surface of the gold; the potential of the gold was controlled with potentiostat. It was observed that an oxide of gold and not chemisorbed oxygen begins to form on gold anodes at a potential of 1.1 V and continues to form at all potentials above 1.1 V until 2 V is reached, at which point oxygen is evolved. When the potential is decreased, complete and rapid removal of the oxide film occurs below 1.1 V. When oxalate ions are present in high concentrations, no oxide film forms on the gold at any potential; or, if it does, it is removed as rapidly as it forms as ellipsometer measurements show no phase change on the surface of the gold.



With this equipment, the performance of three helicopter batteries of silver-zinc and silver-cadmium types can be tested simultaneously under simulated service conditions. **(See page 47)**

Structure of Garnets. Nuclear magnetic resonance techniques were used to study the magnetic characterization of mixed crystals of yttrium-iron-gallium garnets as the ferromagnetic iron atoms are replaced by the "non-magnetic" gallium atoms. The primary objective of the work, which was sponsored in part by the Advanced Research Projects Agency, was to measure the magnetic fields at the nucleus of the ^{57}Fe in these matrials. The nuclear magnetic resonances of ^{69}Ga and ^{71}Ga were observed in these same samples. These latter results are particularly interesting because gallium is a diamagnetic atom and the hyperfine field at the gallium site arises through a transfer of the spin density from the neighboring oxygen atoms, which are in turn polarized by their neighboring iron atoms. Thus, the hyperfine interactions at the gallium are associated with the superexchange interactions between the gallium and the iron.

Ferromagnetic Alloys. The nuclear relaxation times for 1 percent ^{61}Ni in 99 percent iron, 1 percent ^{61}Ni in 99 percent cobalt, and 0.5 percent ^{59}Co in 99.5 percent nickel were measured at several temperatures using the pulsed free precession method. Such measurements give information concerning the motion of domain walls around the impurity atoms. Relaxation time studies on nuclei in the domains relate to the strength of the coupling between the impurity atom spin and the conduction electrons. These results indicate that the strength of the conduction electron relexation mechanism for the impurity nuclei is smaller than for the nuclei of the solvent atoms in the pure solvent metals.

Magnetic Susceptibilities. The electron resonance, optical spectra, and magnetic susceptibilities of pure VCl_4 and of VCl_4 in $TiCl_4$ were interpreted by considering a distortion of the regular tetrahedral crystal field. A small Jahn-Teller tetragonal distortion would fit these measurements, but a packing-type trigonal distortion is also under consideration. Calculations indicate that the resonance, optical spectra, and susceptibilities can be interpreted by invoking a small tetragonal crystal field distortion. Spin-lattice relaxation measurements made on single crystals of Mohr's salt show there are definitely two relaxation times, and for certain crystal orientations a maser effect appears to be present.

A calculation of the complex dielectric susceptibility of ionic crystals was completed. Higher-order effects due to distortion of the electronic clouds around the nuclei were taken into account.

Dielectrics. Techniques were developed to measure viscous liquids inside a polystyrene cup. With this arrangement, the wide frequency capability for measuring solid dielectrics was used to study viscous polyvinyl esters. Measurements from 10^1 to 10^9 Hz verified the validity of the frequency-temperature superposition principle for dielectric relaxation processes above the glass transition temperature. This verification can be expected to lead to a more satisfactory understanding of glass temperature relaxation phenomena.

An extensive experimental study was made of the dielectric relaxation (nonresonant absorption) of several symmetric-top gases (CH_3Cl, CHF_3, and SO_2F_2) and their mixtures with various foreign gases (He, Ar, H_2D_2, CO_2, N_2, CH_4, and C_3F_8). Measurements over an extended temperature range (−20 to 150 °C) determined the variation of the relaxation time and effective collision cross section for molecular reorientation with temperature and their dependence on the nature of the intermolecular forces. Measurements at room temperature were extended to a number of other symmetric-top gases and about 15 other foreign gases. Despite the lack of previous theory, some progress is being made in the theoretical interpretation of the results and in correlating the dielectric behavior with other dynamic properties, such as viscosity.

Advisory Activity. An extensive study of the lightning protection problems associated with steel-framed monumental buildings was completed with the support of the Architect of the Capitol. Several changes were recommended for the Rayburn House Office Building lightning protection.

The Magnetic Measurements Section served as referee on the sale of a large order of silicon steel for use in the electrical industry. When the supplier and the purchaser were unable to agree on the value of core loss for the material, samples of it were submitted to the Bureau for a referee test. After determining the core loss, the Bureau assisted the purchaser in locating the error in his determination.

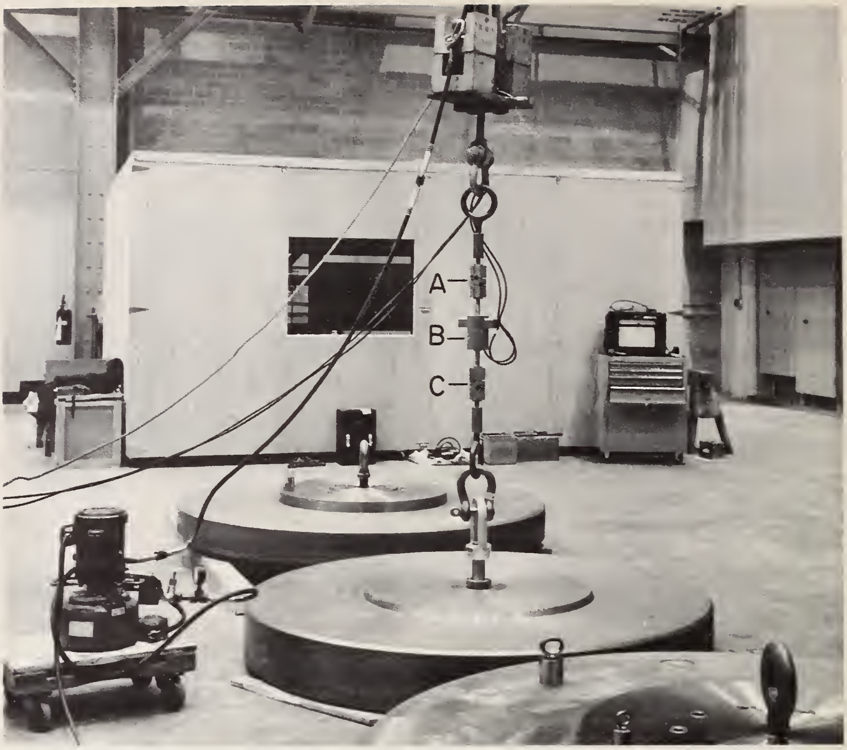
Calibration Service. The large-volume calibration items were 1,576 resistors, 873 standard cells, 580 capacitors, and 332 inductors. The various other items, such as potentiometers, current transformers, volt-boxes, etc., run a few dozen each. In addition, 1,412 dry-cell batteries were tested for the General Services Administration and the Veterans Administration.

2.1.4. METROLOGY

The metrology laboratories of the Bureau maintain, develop, and disseminate standards for commonly used physical quantities such as length, mass, volume, density, and angle, as well as for light, color, electromagnetic radiation, and other optical and photographic quantities.

During the past year advances led to improved measurement capabilities. The development of a load-cell technique for comparing large weights enables other laboratories to calibrate their own weights, thus reducing "down time." A gaseous laser operating in the visible region of the spectrum was built and will be used in the interferometric determination of length. A line standard interferometer, utilizing automatic fringe-counting techniques, was placed in operation; thus both more accurate and more rapid calibrations of line standards are now possible. The use of new equipment and electronic data processing resulted in a reduction in the calibration time for both gage blocks and base-line tapes.

Load Cell Comparison Devised for Weight Calibrations. By means of comparative rather than direct-reading techniques, precisions of 5 parts per million were achieved in the calibration of 10,000-lb weights. This accomplishment, obtained with a load cell, demonstrates that other labora-



Technique developed for load cell comparison of large weights should save millions of dollars by permitting any laboratory to calibrate its own weights. Equipment consists of an hydraulic lift, a flexure (a), a load cell (b), another flexure (c), and a means of hooking on to the weights. **(See page 51)**

tories can use readily available equipment in the calibration of their own weights, and thus eliminate the need for NBS calibrations and the ensuing down time.

The essence of the development is not the assembly of any particular set of equipment but rather the use of established comparative techniques and careful statistical evaluation of the resulting data. The load cell, one of several equally promising elastic devices, was investigated and proved satisfactory. It offers the advantages of precision equal to the best of platform scales, portability, rapidity of weighing, and availability of equipment.

The equipment for the weighings consists of a hydraulic lift, two flexures, a load cell, and a means of attaching the weights, all suspended from an overhead crane. The hydraulic lift is used to raise and lower the weights and thus avoid sudden stress on the cell, and the flexures keep the stress in axial alinement with the cell. A variety of electronic assemblies may be used to determine the output of the strain-gage bridge in the load cell, as long as the entire system is sufficiently sensitive and successive measurements of the same quantity agree or follow a regular trend. Intercomparisons of three 10,000-lb weights made with this equipment gave a standard deviation of 0.04 to 0.06 lb. These results are comparable to those obtained with the best of multiple lever scales.

Color-Matching Functions Evaluated. Industrial inspection of manufactured goods (textiles, paints, plastics, ceramics, papers) for conformity to a color standard is usually carried out at close range so that the parafoveal as well as foveal regions of the inspector's eyes are used. In this way he can detect smaller color differences. Accordingly, in 1964 the International Commission on Illumination recommended color-matching functions intended to conform to observing fields subtending 10 degrees at the eye of the inspector.

The Bureau carried out tests of these functions for moderately bright fields. These tests indicate that the functions sometimes fail to predict the color matches of actual observers with normal color vision, and suggest that the failures are due to a disturbance of the match from responses of the twilight vision part of the eye which, in the parafoveal region, is intermingled with the color-perceiving part of the eye. To eliminate such disturbances, more light than is generally used for color measurements is required.

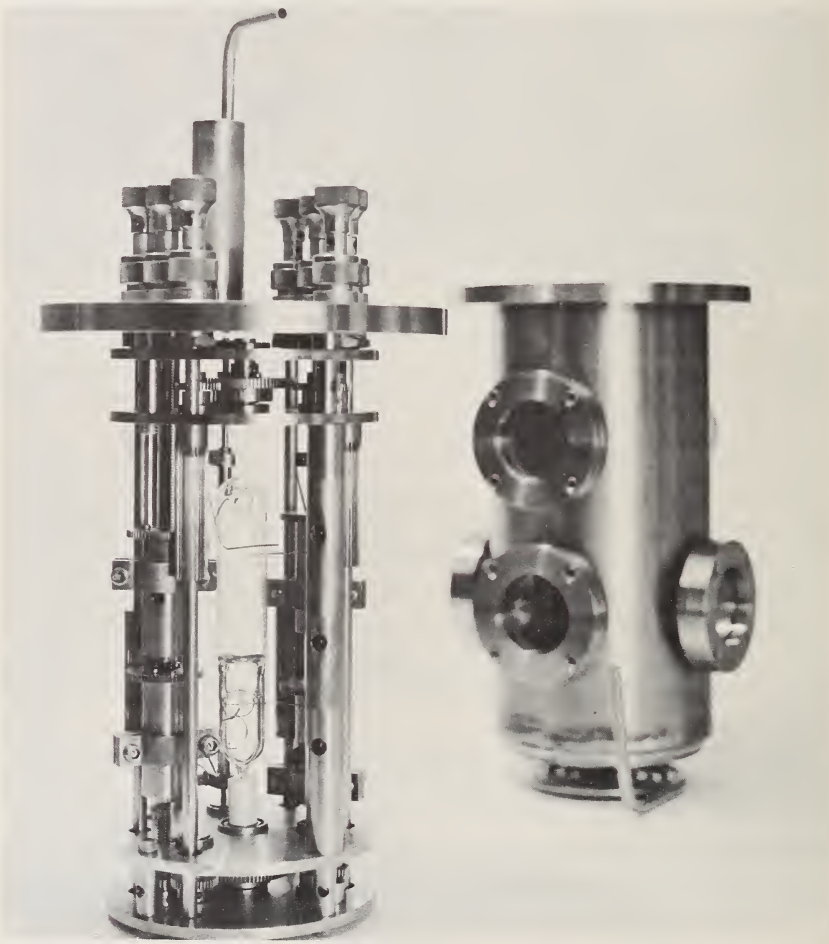
Density Measurements Devised for Small Objects. A Cartesian diver system is being developed for weighing objects too small for reliable observation on ordinary hydrostatic balances. Such balances have uncertainties of 20 micrograms or more; hence, their percentage precision for very small objects is limited. Unfortunately, objects of greatest interest in hydrostatic weighing, for instance, highly purified substances, single crystals, and sensitivity weights, are not readily available in large sizes. In the new technique, density determinations are made by attachment of an object to the outside of the diver and measurement of the pressure in the water that will result in zero vertical movement of the diver.

At present, these hydrostatic weighings can be made reproducibly to a standard deviation of one or two micrograms. Experiments are being conducted on 1-gram objects occupying a volume of about $1/20\ cm^3$. Efforts are being devoted to obtaining volumetrically stable objects which can be used as comparison standards in the weighings. Experiments are now being conducted on nichrome, gold, platinum, fused quartz, and silicon. As soon as stable standards are developed and calibrated against mercury, they will be compared hydrostatically with various single crystals, probably beginning with rutile.

Aging Blemishes Studied on Microfilm. Inspections of microfilms of Government records revealed blemishes which apparently developed long after the films were processed and placed in storage. Most of the blemishes are small spots, usually reddish or yellowish in color, ranging from about 15 to 150 microns in diameter. These blemishes were classified on the basis of size, shape, color, and character. Descriptions and colored photomicrographs of the various types and recommended inspection, sampling, and reporting procedures were published in NBS Handbook 96, *Inspection of Processed Photographic Record Films for Aging Blemishes.* In cooperation with the National Archives, NBS trained 100 microfilm inspectors. These inspectors subsequently made detailed reports on 4,300 rolls of microfilm, a statistical sampling of over 100 million feet of film.

The mechanism of blemish formation and generally accepted preventive measures are not as yet known. The processing and storage conditions in various places are therefore being correlated with the incidence and severity of blemishes; the chemical and physical structure of the blemishes are being studied; and biological and chemical mechanisms of blemish initiation are being investigated.

A protective treatment developed by a microfilm manufacturer shows promise of inhibiting blemish development. Enough empirical evidence was gathered to begin a revision of recommended practices for the preservation of microfilm records. Plans were laid for a joint industry and Government research effort on an expanded scale.



Cartesian Diver System being developed for water-weighing of objects too small for reliable observation with ordinary hydrostatic balances. Reduction of uncertainties from 20 to one or two micrograms has already been achieved.

(See page 53)

Microdensitometer Calibration. In the past, the density scales of microdensitometers have been calibrated by means of photographic step tablets of known densities as defined in the American Standard for Diffuse Transmission Density. This kind of density, however, is inappropriate for the calibration of microdensitometers because the geometry of such instruments differs from the geometrical conditions specified in the American Standard. Hence, a new kind of density was defined, having geometrical conditions of illumination and sensing identical to those employed in microdensitometry. A "standard microdensitometer" was constructed to calibrate photographic step tablets for use in the calibration of microdensitometers.

Photographic Knife Edge Devised. In measurements of the capability of photographic film to produce sharp images, the films are exposed to light while partly covered with a straight knife edge. Since actual metallic knife edges are unsatisfactory for such measurements, a straight-edge x-ray image of a thin tantalum foil was made on a high-resolution photographic film for use as a "knife edge." This photographic "knife edge" is convenient for measuring film characteristics and also for evaluating the spatial response of microdensitometers.

Chlorophyll Measured in Tree Leaves. In 1952–53 the Bureau studied the dying of a mature leaf of a white oak tree, wet and dry, by measuring its spectral reflectance 25 times throughout the year. The regular increase of reflectance obtained in the 680 nanometer region of the absorption band of chlorophyll indicated the gradual disappearance of that plant pigment from the leaf. In the spring of 1964, a similar spectrophotometric study was made of leaves picked from the same branch of a white oak tree at five stages of development starting with a very young leaf and ending with a mature leaf. It was found that the chlorophyll absorption increased with the age of the leaf to maturity, following a pattern that was just the reverse of the pattern obtained in the earlier work. These studies were sponsored by various agencies of the Department of Defense.

Infrared Hazemeter Developed. In cooperation with the Advanced Research Projects Agency, an infrared hazemeter was constructed to measure the forward-scattered flux of infrared transmitting optical materials. The instrument is similar in principle to the visible hazemeter used in ASTM (American Society for Testing and Materials) Method D 1003. Radiant flux scattered by a specimen is collected for measurement in an integrating sphere. The wavelength range of the present instrument extends from the visible region to about 4 microns in the infrared region. Preliminary measurements of several materials indicate that the haze depends on the type of specimen, the thickness, and the batch of material from which the specimens are made. Data of this type will help optical designers select the most suitable material for a particular wavelength region.

Spectral Distribution of Typical Daylight. Determinations of how the energy of daylight is distributed in the ultraviolet and visible portions of the spectrum were carried out in collaboration with the National Research Council of Canada, the Eastman Kodak Company of Rochester, and Thorn

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Aging blemishes on the leader of a 16 mm microfilm. The causes for the appearance of these spots on microfilm records, and possible corrective measures, are currently the subject of an intensive investigation. **(See page 53)**

Electrical Industries, Limited, of Enfield, England. Typical distributions were found ranging from the blue light of the clear sky, through light from the gray overcast sky, to the yellowish combined light from the sun and partly cloudy sky. This information will be useful in establishing standards of artificial daylight for the color appraisal of industrial materials and manufactured goods of all kinds (textiles, paints, plastics, papers, ceramics); but it is particularly useful for the appraisal of optical bleaches that make textiles whiter by transforming some of the incident ultraviolet energy into blue light. Artificial daylight currently available for this appraisal has insufficient ultraviolet content.

Fluorescent Lamp Color Standards Recalibrated. The fluorescent-lamp industry has been maintaining the colors of its warm white, white, cool white, and daylight lamps by using laboratory color standards. The calibrations of these standards are based on standards of the same colors calibrated at NBS eight years ago by a visual match with incandescent lamp-and-filter combinations of known chromaticity. Spectroradiometry, the fundamental method by which fluorescent-lamp standards should be calibrated, previously gave systematic differences that were larger than the tolerable uncertainty.

As a result of recent progress in cooperation with the laboratories of the lamp manufacturers, NBS has now recalibrated spectroradiometrically the four groups of laboratory color standards that were furnished originally. This recalibration of the same lamps provides the industry with data on the magnitudes of the color differences ascribable to the change in calibration method. The spectroradiometric method also provides data that permit calculation of the color rendition of objects illuminated by the lamps. Information on the color-rendition characteristic of a light source is apt to be of more interest to the ultimate user than the chromaticity of the lamp itself.

Check Made of Color-Temperature Scale. Light sources for the color appraisal of industrial materials and manufactured goods, and for appraisal of the performance of photographic materials and photocells, are all defined by reference to gas-filled incandescent lamps of known color temperature. The present NBS color temperature scale is based on three fixed points established in 1934 for the kinds of light coming from a cavity whose walls are maintained at one of three known high temperatures, namely, the freezing points of platinum (2,042 °K), of rhodium (2,233 °K), and of iridium (2,716 °K). Laboratory reference standards for color temperatures up to 3,200 °K have been calibrated three times since 1934 by means of blue filter standards.

Comparisons in 1960–62 with similar standards calibrated at the National Physical Laboratory in Great Britain indicated a discrepancy greater than the uncertainty estimated for the calibration by about a factor of three. The NBS color-temperature scale above 2,716 °K was recalibrated this year by the use of more filters and more cross-checks than were previously used. The resulting adjustment in the color-temperature scale is such that at 2,854 °K, for example, the voltage at which an incandescent lamp must be operated has been increased by about 0.8 percent. This adjustment corresponds to about 9 °K and is only slightly larger than the NBS estimate (7 °K) of the uncertainty. The adjustment also reduces the difference between the American and British scales.

Standard Published for the Colors of Signal Lights. Traffic of all kinds (highway, railway, marine, and aviation) is controlled by colored lights, and 15 different colors (three varieties of red, yellow, green, blue, and white) denote the various required meanings involved in long- and short-range signaling. The Bureau, through the U.S. National Committee on the Colors of Signal Lights, led the way toward a coordination of these various colors. This coordination involved a unified method of defining the colors, a standard method for testing signaling devices for conformity to the color requirements, and a selection of the glass standards of color to be used in the standard method. The agreement achieved by eight agencies of the Federal Government, five national associations, and four manufacturers of components for signaling equipment is given in a new publication, NBS Handbook 95, *U.S. Standard for the Colors of Signal Lights.*

Wavelength Standards for Spectrophotometers. For over 20 years the Bureau has issued commercial "didymium" glasses, together with a report of the wavelengths of the sharpest of the absorption and transmission bands, to users of spectrophotometers for checking the wavelength scale in the visible and near-infrared regions. With the advent of photoelectric recording spectrophotometers for the ultraviolet, a commercial glass containing the oxide of the rare-earth element, holmium, similarly calibrated was made available. The search continued, however, for glasses exhibiting more and sharper lines over a broader wavelength range.

Recently, measurements were made of phosphate-base glasses (fabricated in the NBS glass laboratory) containing the oxides of one, two, three, or four of the rare-earth elements, to determine which combination of oxides would result in the most useful standard. This study indicates a combination of two glasses, one containing the oxides of neodymium and samarium, the other those of holmium and ytterbium, to be the most useful. This study was financed in part by the Advanced Research Projects Agency of the Department of Defense.

Master Balls Rapidly Calibrated by Interferometry. Requests from spacecraft industries for calibrated master balls increased greatly over the past two years. An instrument was therefore designed and built to measure rapidly and in a horizontal plane all sizes of balls up to one inch in diameter. A complete set is stored on two turret tables and is fed by remote control to an exact position between two interference plates. Positioning of these plates is accomplished by an electric motor, but the orientation of the interference fringes for exact fringe fraction readout is controlled by a micropositioning system employing air pistons and flexure levers. Measurements are made on a ball on six or more randomly selected horizontal diameters with a known applied force repeatable to less than 1 gram. The man hours for diameter calibration are reduced by a factor of 7 with the new instrument.

Tooth Index Positions Measured on Large Gears. By means of an improvised assemblage of available components, deviations from correct angular positions of gear teeth of a 20-in. pitch diameter gear were determined to a precision of 2 arc-seconds and an accuracy of 5 arc-seconds. On the basis of these results it appears that a tooth-index measuring machine having a capacity of approximately 100-in. diameter could be designed and built. Such a machine would be a valuable tool in improving the reliability and noise reduction of large gears.

Roughness Simulator Constructed. In a recently constructed roughness simulator, a piezoelectric crystal driven by a generator provides a series of periodic waveforms that are imposed upon an analyzer's transducer. The equivalent roughness height of each wave can be determined by interferometric measurements and compared to the indicated value of the analyzer. The simulator offers a significant improvement over existing techniques because of its capability for varying the waveforms' parameters. It is being used for measurements of the finer finishes that cannot be measured by the mechanical standards presently in use.

Spectrometer Designed for Laser Analysis. A spectrometer was designed to study the spectral output of lasers and other light sources. Essentially, the instrument is a Fabry-Perot interferometer of variable plate separation, with a photomultiplier tube viewing the center of the interference ring pattern through a small circular diaphragm. A piezoelectric ceramic tube, whose length is varied by applied voltages, is used as a spacer between the two interferometer plates. As linear changes of the interferometer plate separation are produced in this manner, the photomultiplier tube scans through the interference pattern.

With a steadily varying d–c voltage applied to the piezoelectric tube, a graph of the spectral intensity distribution is obtained with a chart recorder. High-frequency noise is easily suppressed by limiting the frequency response of the recorder and recording at low speeds; this method is therefore particularly suitable for the analysis of the fine and hyperfine structures of weak spectrum lines.

An a–c voltage at the tube and display of the phototube output on an oscilloscope screen provide the time-resolving spectrum of the light source. This method lends itself to the detection of instabilities of the frequency output of lasers, for which it is presently used.

Special Optical Calibrations Carried Out. Two calibrations performed during the past year were unusual in both the nature of the measurements and the high accuracy required. The first of these was the calibration of a multiple-camera device which is used in three-dimensional photography of nuclear reactions that take place in a hydrogen bubble chamber. The calibration involved the location of the principal point of autocollimation for a target at a finite distance (213 cm in front of the lens) for each of four miniature precision-type photogrammetric cameras. In addition, the principal point had to be located with respect to a coordinate system determined by three, instead of the customary four, fiducial markers. The four cameras are located in a large metal plate about a central opening, and the lens of each camera is not centered with respect to the picture area. The deviation from parallelism of each of the four image planes was determined with respect to a common plane perpendicular to the axis of the system. Also determined were linear relationships to the nearest hundredth of a millimeter and angular relationships to the nearest second existing between the principal points of autocollimation of the four cameras.

The second calibration, performed for the U.S. Army Engineers, involved the measurement of distortions existing in the image plane at a 5 to 1 enlargement of six ultrawide angle projection lenses. This task was unique in that the total angular field was 120 degrees instead of the usual 45 degrees. In addition, very tight tolerances required that all values of distortion referred to the short conjugate distance be correct to within ± 2 microns. In the course of this work, several new analytic methods were developed for checking the results of measurement. As a byproduct of the research, it was found that the optimum magnification ratio resulting in minimum overall distortion could be predicted.

Refractometric Research. To demonstrate superachromatism without interference from monochromatic aberrations, a five-element prism was designed and constructed. According to computations, this prism will deviate a beam of light 27.5 degrees with no aberration greater than ± 4 seconds over a spectral range all the way from 4,047 Angstrom to 1.014 micron.

The aberrations of an ordinary achromatic prism producing the same deviation would be in excess of ± 50 seconds over a more restricted spectral range.

Ophthalmic Lenses. A newly published American Standard, "American Standard Prescription Requirements for First Quality Glass Ophthalmic Lenses," incorporates the recommendations and suggested tolerances for refractive power contained in an NBS study of spectacle lens performance made for the Veterans Administration.

Line Standard Interferometer. An interferometer designed to calibrate length scales in terms of the international standard of length—the wavelength of light—was subjected to initial trial tests. The results were extremely promising, indicating the instrument is precise to within 2.5×10^{-5} mm and has an accuracy that will advance the state of the art of line standard measurement. Simple straightforward calibrations by the line standard interferometer agreed with results obtained by long painstaking calibrations performed by older conventional methods.

Thermal Expansion Calibrations Expanded. Two instruments designed to increase the temperature range of thermal expansion measurements were constructed. The high-temperature instrument (up to 1,600 °C) to be used for calibration of standard samples for high-temperature dilatometers and for the investigation of the expansion of materials at extreme temperatures, is undergoing final tests. One of the first assignments of the low-temperature instrument (down to -250 °C) will be the determination of the thermal expansion of vitreous silica. Such information is applicable to sonic interferometer determinations of a low-temperature scale.

Superprecision Gaging. The monitoring of stability samples of steel and determinations of length changes with aging of numerous steel alloys continued, in studies carried out in cooperation with the Bureau's metallurgy laboratories (see p. 141). Work also progressed on the use of polarized light to determine contact error in end standard gaging. The results thus far obtained, combined with an analysis of the propagation of errors involved, indicate a present day experimental limitation to an accuracy of approximately 0.5×10^{-6} mm. This accuracy is sufficient; however, effort is being directed toward making it more easily achievable.

Mössbauer Radiation. The metrology applications of the Mössbauer effect were further investigated, and a high-precision Mössbauer spectrometer was developed. This spectrometer, using a fringe-counting technique, can measure velocity in the range of 0 to 5 cm/sec with a precision of 1 part in 10^4. The instrument will be used to calibrate Mössbauer absorbers and for evaluating Mössbauer sources. Such information is required for the development of a Mössbauer geodimeter, for which a feasibility study was made. The study showed that an accuracy of a part in a million could be obtained in a geodimeter having a 50-meter range, even without controlled ambient conditions.

2.1.5. MECHANICS

The Bureau's work in mechanics is primarily in the development and improvement of methods of measurement of mechanical phenomena in solids, liquids, and gases; the establishment of required standards in mechanics and the relation of such standards to the prototype standards; the support of these activities by theoretical and experimental researches into mechanical phenomena; the determination of physical constants of particular importance in mechanics; and provision of assistance to other laboratories in relating their measurements to a common basis (or to established standards) by transfer standards, calibration services, and other means. Measurement areas include sound pressure and intensity, shock, vibration, force, strain, pressure, vacuum, viscosity, and rate of gas and liquid flow.

These measurements areas are of great importance in science and engineering, including the missile and space programs, which require great accuracies over widely extended ranges under extreme temperature environments. Special emphasis is therefore given to research directed toward meeting these needs.

Most of the equipment used by the staff of the Engineering Mechanics Section was moved to the new special-purpose Engineering Mechanics Laboratory at Gaithersburg, Md. The employees engaged in the calibration of force-measuring standards will continue to provide calibration services in this area with the equipment located in Washington until the new equipment being installed at Gaithersburg is ready for use. All of the weights for the new 112,000-lb and 300,000-lb capacity deadweight machines have been received and work on the adjustment of these weights is nearing completion. Several of the 50,000-lb weights for the 1,000,000-lb capacity deadweight machine have been delivered. Construction of the 12,000,000-lb capacity testing machine due for completion late in 1965 was started. Design work progressed on the Sound and Fluid Mechanics Laboratories.

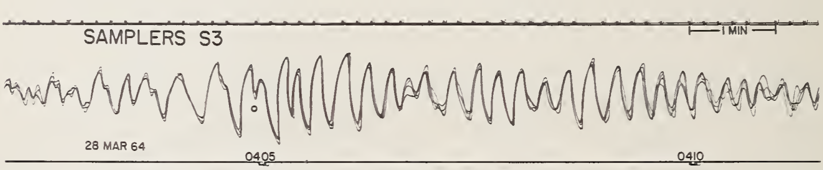
Calibration of Microphones. Microphones are calibrated in two different ways. In one way, a known sound pressure is applied to the diaphragm at various frequencies, yielding a "pressure sensitivity." In the other way, the microphone is placed in a plane wave having a known sound pressure; then the sound pressure at the diaphragm is different because of diffraction by the microphone. The latter way yields a "free-field sensitivity."

The ratio of the free-field sensitivity to the pressure sensitivity (known as the free-field correction) of a group of laboratory condenser microphones was measured by performing separate absolute calibrations to obtain the two types of sensitivities. The free-field correction is of importance because the free-field sensitivity is often determined by measuring the pressure sensitivity and multiplying it by the free-field correction, which is assumed to be the same for all microphones having the same external dimensions. The Bureau's measurements uncovered differences in the free-field corrections between microphones of as much as 9 percent, indicating that the use of a "standard" free-field correction can result in errors. The only method presently known of avoiding such a systematic error is to perform microphone free-field calibrations in an anechoic chamber, either by reciprocity or by comparison with a microphone calibrated by reciprocity.

Measurement of Earthquake Motions by an Acoustical Technique. The great Alaskan earthquake on Good Friday in 1964 produced unusually large motions of the earth's surface in the Washington, D.C., area. The unexpected motions were so great as to make accurate measurements by conventional seismometers impossible. But the strong motions of the Rayleigh waves from the earthquake produced, as they passed through the Washington area, sound waves in the atmosphere. Although these occurred at a frequency far too low to be heard, they were nevertheless measured by the infrasonic microphones of our Washington station. The sound pressures were in fact about 40 dynes/cm^2, at a period of oscillation of about 25 seconds. From this it was deduced that the earth motion in the Washington area was almost 2 inches from trough to crest. The microphones with which the pressure measurements were made are located at various sites in Montgomery County, as well as at the Bureau's site in Washington. An interesting feature of the measurements is that the sound pressure represents motion of the earth's surface averaged over a very considerable area, of the order of several hundred square miles. This is to be contrasted with measurements by a conventional seismometer, which gives the actual motion of the earth at the particular point where the seismometer is located.

The entire sequence of acoustical phenomena caused by the passage of the earthquake waves through the Washington area occupied a period of several hours. Particularly puzzling are some waves which seem to have been scattered by the Gulf of Mexico, with some of the scattered waves reaching Washington. The geophysical causes of the scattering are still being investigated.

Sound Insulation in Buildings. In recognition of the serious problem of privacy-invading noise in multifamily dwellings, projects on sound insulation have been undertaken, leading eventually to residential noise control. FHA's activity in this field led to that agency's recent publication, "Guide to Impact Noise Control in Multifamily Dwellings." The Bureau is cur-



Superimposed recordings from four spaced infrasonic microphones show atmospheric sound waves caused by Rayleigh waves from the great Alaskan earthquake passing through the Washington, D.C., area. These recordings indicate a total earth motion of almost 2 inches, too large a movement to be measured accurately by conventional seismometers. **(See page 62)**

rently engaged in a second study under FHA sponsorship dealing with the technical control of both airborne and structure-borne noise in multifamily dwellings. Airborne noise emanates from sources which radiate directly into the air, such as loudspeakers, musical instruments, the human voice, barking dogs, etc. Structure-borne noise by contrast is produced when wall, floor or other building structures are set into vibratory motion by direct mechanical contact with such noise sources as air-conditioning equipment, dishwasher and disposal units, etc. The vibration is transmitted in various ways throughout the building structure and is re-radiated as noise in other areas.

A summary publication, NBS Monograph 77, *Sound Insulation of Wall, Floor and Door Constructions*, currently in press will contribute to the FHA study. This publication contains acoustical test data and constructional details of a wide variety of building assemblies useful in the control of both airborne and impact or structure-borne noise.

A roundrobin interlaboratory study of the impact sound transmission through concrete floor structures and a companion field study on nominally identical floor structures in existing buildings were completed, and the first draft of a "Tentative Recommended Practice for Laboratory and Field Measurement of Impact Sound Transmission" was written. This work, which has been supported in part by the Army, Navy, and Air Force, will continue until a standard method of test is adopted. The importance of this activity is reflected in the fact that the eventual formulation and enforcement of noise control criteria in building codes will hinge primarily on the development of a reliable field test capable of checking building conformance with acoustical requirements.

The combined efforts of the FHA and the Sound Section of NBS in the field of residential noise control are providing much-needed guidance to architects, builders, building code authorities, and others involved in the design and construction of multifamily housing projects.

Audiometry. People usually hear by sound waves which travel down the ear canal to the ear drum (air conduction). But sounds can also be heard when a vibrator is applied to the bones of the head (bone conduction). The relative sound levels of hearing by air conduction and bone conduction are important in the medical diagnosis of impaired hearing.

One can make a quantitative measurement of this relationship by simultaneously impressing an audible pure tone signal through earphones on the two ears of a subject, and through a bone vibrator applied to the forehead. Each signal contributes to the displacement of the basilar membrane in the inner ear. By an adjustment of the magnitude and phase of the signals on the earphones, the air-conduction signal can just cancel the bone-conduction signal and the subject will hear nothing.

Apparatus, which included the design of a precision phase shifter continuously adjustable over 360°, and constant in output amplitude to within I dB over the audio-frequency range, was constructed to measure the "bone-air null." Preliminary results were obtained.

There is at present no standard method for calibrating the bone vibrators used in the measurement of hearing. For a proper calibration, the vibrator should be loaded with a mechanical impedance equal to that presented to the vibrator when applied to the bones of the head. That is, an artificial head-bone is required. With the help of the Bureau's digital computer, results of measurements of the mechanical impedance of the forehead and mastoid made here and at the National Physical Laboratories in England were combined for a vibrator designed to meet the requirements of the International Organization for Standardization. The combined impedance values expressed in terms of an equivalent four-parameter mechanical network, valid from 250 to 6,000 Hz, were presented to ISO to form the basis for the design of a standard artificial head-bone.

The present proposed ISO standard for threshold of hearing by air conduction is in terms of five earphone-coupler combinations, described in the national standards of five countries. In order to facilitate calibration of audiometers, we have prepared a tabulation of the sound pressures corresponding to threshold produced by the five national standard earphones and by six other commercially available earphones in one coupler, the Bureau's 9A Coupler, now in the process of being reported by the International Electrochemical Commission as an interim reference standard coupler.

Single-Crystal Ice—Elastic Constants. It has been known since 1959 that the thermal properties of regular ice as deduced from the elastic constants measured just below the ordinary freezing point, are at variance with those measured directly at very low (i.e., liquid helium) temperatures. The Bureau is engaged in a search for a low-temperature vibrational mode of the ice lattice which might resolve the discrepancy.

The elastic constants are calculated from fairly high-precision measurements of the speed of longitudinal and transverse sound waves in single-crystal specimens. A pulse-coincidence technique has been developed for this purpose.

Some difficult problems, which it is hoped will be solved soon, stem from the instability of ice in the ordinary environment. The dimension and orientation of the crystals must be measured, and the machining of specimens done, in a cold (-40 °C), very dry atmosphere.

Nonlinear Distortion in Hearing Aids. A hearing aid, like other nonlinear electronic amplifying devices, produces frequencies in its acoustical output which can be audible, and which are not present in the input sound signal. This nonlinear distortion has been evaluated in the past by introducing one frequency, or sometimes two frequencies, into the input signal to the hearing aid and measuring the frequency and amplitude of any spurious components in the output. However, it is not convenient and sometimes not possible to determine by this method the distortion which will be produced when the input sound is a complex signal having many frequencies such as speech.

In work sponsored by the Veterans Administration, a method has been developed in which the input signal has a distribution of energy (at frequencies and amplitudes) which is similar to that of a speech signal, except that a large attenuation is introduced at a number of frequencies in the spectrum. The acoustical output of a hearing aid, both at frequencies at which the acoustical input signal is attenuated and at other frequencies as well, is measured. From such measurements is obtained an evaluation of the nonlinear distortion produced by the hearing aid when it is amplifying a speech-like signal.

Electromechanical Coupling Factor of Condenser Microphones. A new and very direct method was developed for obtaining the electromechanical coupling factor of condenser microphones by means of static pressure measurements with a low-pressure manometer, and d-c voltage measurements. The procedure consists of applying a static pressure to the diaphragm of the microphone and adjusting the polarizing voltage to keep the diaphragm in its equilibrium position, which is observed by means of a carrier-frequency circuit. Measurements were made over a range of static pressures up to 360 newtons/meter^2 and up to changes in d-c voltage of about 200 volts. Over these ranges, the measured coupling factor was constant within approximately ± 0.3 percent. Values of the coupling factor were compared with determinations made at audio frequencies and found to agree within 1 percent.

The significance of this agreement is twofold. First, it indicates that the coupling factor can be used as a microphone sensitivity measure for sound pressures in the infrasonic frequency range, since the factor appears to remain constant as the frequency approaches zero. Second, since two independent methods for determining the coupling factor yield the same result, the assumptions and measurement techniques leading to its determination seem to be reliable. These techniques include the reciprocity method for calibrating microphones which the Bureau uses to determine the absolute sensitivity of reference standard microphones.

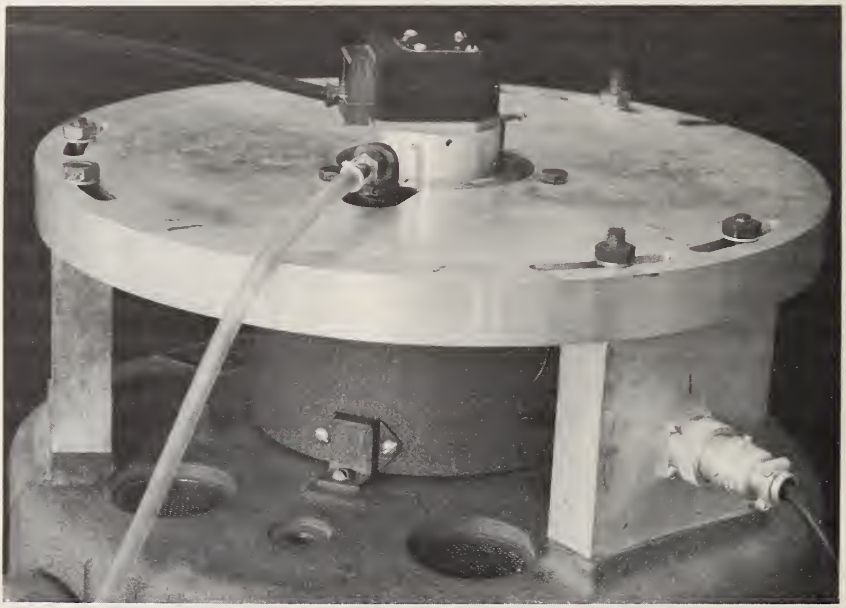
Pressure Measurements. The wide and still-expanding range of pressures used today in industry and science calls for continuous improvement of existing methods of pressure measurement and calibration as well as for the development of new techniques. A program has been initiated for the measurement, with improved accuracy, of the transition pressures for changes in the crystalline form of bismuth (the so-called Bi I–II and Bi II–III transitions near 400,000 psi), in order to meet the demand for improved fixed points on a high-pressure scale. The state of the art in the 100-kilobar range (1,500,000 psi) was improved by a study of the behavior of silver chloride as a pressure-transmitting medium in pyrophyllite and reconstituted mica gaskets.

For a greater accuracy in the measurement of low pressures, an improved point-gage-type mercury manometer, developed at the Bureau, has been adopted by a number of Bureau laboratories, and may prove to be the standard of choice for the calibration of anemometers used in manned aircraft flying in the 50,000- to 100,000-ft range.

Damping of Surface Waves Caused by Turbulence. A laboratory investigation was conducted under the sponsorship of the Office of Naval Research to determine whether turbulence in water has a damping action (expressible in term of an eddy viscosity) on surface waves. The experiments were conducted in a wave tank. Although laboratory conditions could not be expected to simulate any specific phenomenon, an attempt was made to create "turbulence" in the tank by upward directed water jets from orifices uniformly distributed over the tank bottom, with a duplicate set of intake orifices interspersed to maintain constant water level. The wave amplitude attenuation along the length of the tank was observed with and without operation of the jets.

The increase in damping with jet operation was small and difficult to isolate from other effects. Owing to the other effects, damping due to jet-induced turbulence was more easily measured with deep-water waves than with shallow-water waves. This damping could be ascribed to an eddy viscosity which for deep-water waves was approximately 15 times the viscosity of water, for the conditions investigated.

Highway Culverts. Research in culvert hydraulics conducted at NBS under the sponsorship of the Bureau of Public Roads established that the water-carrying capacity of highway culverts can be substantially increased. A culvert (the pipe or duct under the road) does not generally flow full even though the entrance may be fully submerged; the principal factor influencing this condition is the shape of the entrance.



Increased calibration accuracy and stability has been obtained in electrodynamic vibrators by using air bearings. Here, a velocity pickup is mounted on the moving element for calibration. Tube in foreground supplies air to the bearing.
(See page 66)

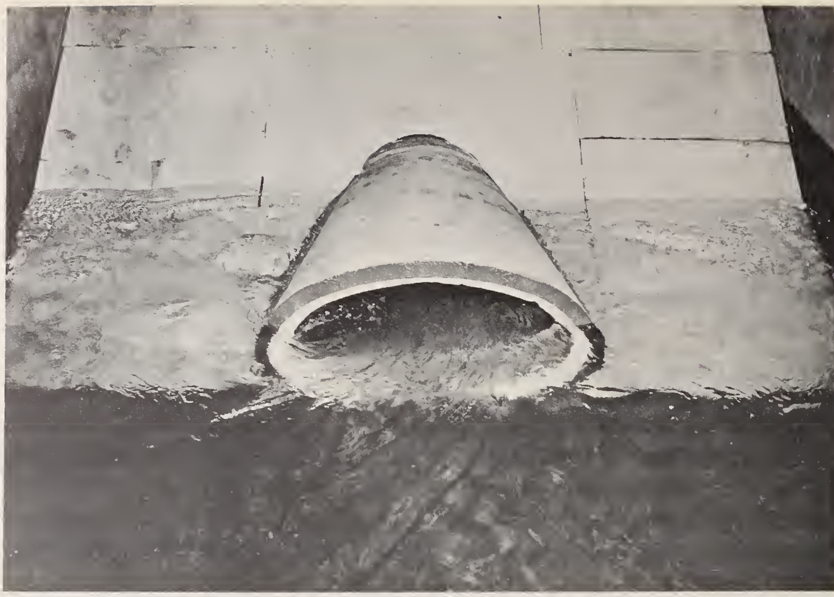
In the NBS study of culvert hydraulics, emphasis was placed on the design of entrance shapes to promote greater capacity. By the use of tapered inlets, the flow capacity of culverts can be increased from 50 to 75 percent above that obtained with commonly used entrance designs. This work was done in the laboratory with model sizes ranging from 6 to 30 inches in diameter. Investigations over this range of sizes showed that the performance of a full-sized culvert could be adequately predicted over a useful range of operating conditions from the small-scale model studies. In the field, culverts may be as large as 10 to 15 feet in diameter and may on occasions exceed this size. Since Federal and State costs for the construction of culverts and similar drainage structures for highways approximate $400,000,000 per year, the research work on culvert hydraulics promises to yield significant savings.

New Proving Ring Calibration Report. A new and more convenient proving ring calibration report was issued by the Bureau to replace the calibration graph which required interpolation and tabulation by the user. The new report contains a load versus deflection table and statistical information of the standard deviation of a deflection reading and the standard error for a tabled load value. The validity of the statistical information and the load versus deflection table values given in the report were both verified experimentally.

Displacement Measuring Devices Evaluated at Elevated Temperatures. To evaluate displacement measuring devices under adverse temperature conditions, apparatus was developed to produce displacements known to within 25 microns at temperatures as high as 260 °C. Equipment for measuring the electrical characteristics of differential transformer type transducers was also developed. Using these systems, evaluation tests were conducted on differential transformers over the temperature range of 25 to 260 °C to determine their calibration factor, linear range, zero shift with temperature, and zero shift with time.

Fatigue Strength of Aircraft Structures. Fatigue tests were carried out on a series of 2024–T3 aluminum-alloy riveted joints at room temperature and at elevated temperatures to provide information pertinent to the development of supersonic aircraft. As a basis of comparison, fatigue tests were also performed on smooth sheet specimens. Results suggest that the temperature effect on fatigue of riveted joints is considerably less serious than it is for smooth sheet specimens, particularly in the high-cycle, safe-life regime. Furthermore, it was found that no significant creep took place beyond the first cycle or two, despite the fact that tests were conducted with positive mean loads. This is expected to simplify design procedures in which a synergistic interaction between creep and fatigue in structural components is anticipated. Although the results are not yet fully evaluated, it appears unlikely that dependable fatigue correlations between joint and sheet behavior will be found.

Test Methods Developed for Aeronautical Fasteners. Standardized test methods for determining the mechanical properties of aeronautical



Research on culvert hydraulics promises significant savings in highway construction costs. Here, a tapered inlet increases culvert flow capacity by 50–75 percent over commonly used entrance designs. **(See page 68)**

fasteners are necessary for comparisons between types and materials. Under sponsorship of the Bureau of Naval Weapons, examinations were made of the factors influencing the values of single shear strength for high-strength aeronautical fasteners. Experimental studies were made of these factors as applied to high-strength blind fasteners in aluminum alloy sheet and plate.

Vibration Standard Modified with Air Bearings. By substituting two external-pressure, hydrostatic-type air bearings in a commercial electrodynamic vibration exciter for the mechanical supports of the moving element (armature), the amplitudes of transverse motions were reduced substantially. An ideal exciter used for calibration of vibration pickups should produce axial displacements without transverse motions of the moving element over its full frequency range. The modified exciter, used as a vibration standard from 10 to 2,000 Hz, made it possible to study the performance of pickups sensitive to transverse motion.

Rheological Constitutive Equations. A number of materials, such as rubbers and plastics, flow like liquids under sustained forces, yet recover more or less like elastic solids when the forces are removed. To describe the mechanical behavior of such materials in isothermal situations, a constitutive equation has been developed based on the concept that the elasticity of the material arises from energy related to both the present configuration of the material and configurations in the past but with the influence of past configurations diminishing as we go to the more distant past.

This theory predicts that three material functions (of time) are adequate for isothermal simple extension. These functions were calculated from measurements made in stress relaxation, and then used to calculate successfully the results of measurements involving multiple step stress relaxation, creep and recovery, and constant rate of deformation, all for a particular sample of polyisobutylene.

To extend this description of material properties to include nonisothermal phenomena, it is necessary to create a thermodynamic theory valid for situations far from equilibrium. A non-equilibrium thermodynamics has been found which seems to have the correct qualitative behavior. This theory includes a principle of time-temperature superposition, is consistent with the second law of thermodynamics, and predicts that the temperature increases when work is done adiabatically on a material held at constant volume and decreases when the material does work. The theory also agrees with measurements of apparent viscosity as a function of temperature and rate of shear.

Failure of Aircraft Fuel Hoses. An investigation sponsored by the Bureau of Naval Weapons of the failure of thermoplastic fluorocarbon fuel hoses resulting from the generation and discharge of static electricity produced by flowing fuel was completed. These hoses are used extensively to interconnect the various fuel handling components of aircraft and other internal combustion engines. It is essential that their performance be both safe and reliable.

The investigation established that conventional thermoplastic fluorocarbon hose would fail as a result of static electricity under normal operating conditions. Extensive tests were undertaken to determine the effect of fuel flow rate, fuel contamination, water, hose material, and fuel filter element material on this phenomenon. From these tests, the maximum anticipated electric currents under service conditions can now be accurately predicted.

Assistance was given to the Bureau of Naval Weapons in devising measurement techniques and determining certain properties of fuel hoses to be used in purchase specifications. The Air Force and several major aircraft engine manufacturers expressed the intention of using the revised specifications for future purchases of thermoplastic fluorocarbon fuel hose.

Flow Field of a Flame. Flame speed measurement and design of combustion systems may be improved through a better understanding of a flame's flow field. A study of the field was carried out by the use of a flame front simulated by an assembly of fluid sources and sinks in a general stream.

The direction and speed of the flow on both sides of the flame were obtained by computer techniques from an equation based on the source and sink arrangement. The boundary shapes necessary to experimentally reproduce the flame front were also derived in the computation.

Thermocouple Reference Tables Compiled. Several new noble metal thermocouples were developed for accurate measurement of temperatures of oxidizing gases. Reference tables of temperature versus thermal emf were compiled for the Platinel II thermocouple and several other thermocouples having varying percentage compositions of iridium-rhodium alloys versus iridium.

Reference tables for the Platinel II thermocouple are based on the calibrations of 27 thermocouples. The tables cover the temperature range from −100 to +1370 °C. Reference tables for 60 percent iridium−40 percent rhodium alloy versus iridium and for 50 percent iridium–50 percent rhodium alloy versus iridium thermocouples, published in the past year, extend from 0 to 2150 °C.

2.1.6. HEAT

Heat measurements, standards, and related research play a most important role in modern science and technology. The Bureau discharges important responsibilities in these areas through the maintenance of the National standards for such heat measurements as enthalpy, heat capacity, and heat of combustion. Internationally agreed upon temperature standards are maintained to assure a common scale upon which all temperature measurements are based. A strong research program aims to keep these standards adequate for the expanding scientific needs. In addition, supporting research on the physical properties of solids and gases at both low and high temperatures includes studies in low-temperature physics, statistical thermodynamics, high-temperature processes, high-pressure thermodynamics, and various aspects of plasma physics.

A program extending over many years culminated in the development of a precision mercury manometer having the highest accuracy ever attained. A new spectroradiometer reduces uncertainties of spectral radiance calibrations by a factor of 5 and extends the range of wavelengths covered to 2,000 Å. A facility for calibrating germanium resistance thermometers over the region 2 to 5 °K was established. A rugged and highly reproducible null-type transducer for high-pressure measurements was developed. The automation of precise heat measurements was furthered by completion of an automatic resistance bridge with an equivalent temperature precision of 0.0001 °C.

Research items of major interest include the discovery of superconductivity in oxide semiconductors at very low temperatures; a theoretical treatment of quantum effects in the thermodynamic and transport properties of the light gases; concordant measurements of the electron density in a magnetically confined arc plasma by a variety of methods, and derivation of a dispersion relation for the standing hydromagnetic wave and of a relation between the density correlation function and the diffusion coefficient; measurement of lifetime and spectra of short-lived simple molecules by pulse-spectroscopy and by study of the afterglow from high-frequency electric discharges in flowing gases; development of greatly improved methods for producing gaseous free radicals within microwave cavities and thus for obtaining very accurate data on line frequencies for simple free radicals of astrophysical interest.

Paramagnetic Resonance in Gases. A technique was found by which dense vapors of the hydride radicals of sulfur, selenium, and tellurium are produced. This technique, which involves reactions of atoms at solid surfaces, was used to measure and interpret the electron paramagnetic resonance (EPR) of these elements, and is being investigated further as a means of producing the astrophysically important radicals SiH and CH.

The chemical reaction between atomic hydrogen and NO_2 was found to produce large quantities of OH radicals at total pressures as low as 1 micron of mercury. Eliminating pressure broadening at such low pressures made possible measurement of the 18-cm absorption spectrum of OH to an accuracy of one part per million in the line frequencies. These frequencies will be useful for determining Doppler shifts in the recently observed interstellar absorption spectrum of OH.

The EPR spectra of several rotational levels of ^{14}NO and ^{15}NO were measured and interpreted to determine magnetic moments, hyperfine structure, and Λ-type doubling in these two molecules. This work is supported in part by the Office of Naval Research.

Molecular Energy Levels of Small Molecules. Transient species were studied within a short time after their formation by two methods. The first involves study of the afterglows from high-frequency electric discharges in flowing gases with time resolution as short as about 100 microseconds (μsec.). The admixture of gases downstream from the discharge was used to study the results of collisional processes between the metastable helium and the added species. Of particular interest, in this regard, has been the strong preferential excitation of the ionic spectra of the added molecules.

The technique of kinetic spectroscopy is the second approach used to study transient species. A high-intensity pulse of light causes a gaseous or solid sample to decompose, and the absorption spectrum of the species thus formed is recorded by using as a continuum the radiation from a second high-intensity flash. The second flash follows the decomposition flash at a preselected time interval (which may be as short as 10 μsec). The time history, from 10 to 1,000 μsec, of the vibrational energy of oxygen molecules formed in the photolysis of nitrogen dioxide was studied with this method. In another experiment, the formation of iron oxide was observed following the flash vaporization of iron wire in oxygen.

Plasma Transport Processes. The microwave reflection technique developed by S. Takeda and T. Tsukishima from the University of Nagoya, Japan, was, with their collaboration, successfully applied to determine spatially resolved electron densities in the magnetically confined arc plasma. The results are in good agreement ($\pm$20 percent) with densities determined from the width of Stark-broadened Balmer series lines of hydrogen and from the ion saturation current to a Langmuir probe.

The standing hydromagnetic wave which appears on the plasma column of this arc appears to obey a theoretically derived dispersion relation. This wave is of interest because its phase velocity is dependent on the mass density of the plasma for sufficiently small wavelengths, and it may contribute to cross-field plasma transport.

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The relation between the density correlation function and the diffusion coefficient was extended to the plasma in a magnetic field. This extension may provide a novel and useful experimental technique for the determination of plasma diffusion coefficients.

Microsecond Thermodynamics. A program was undertaken to develop new techniques for the measurement of thermodynamic and other properties of dense substances (in solid, liquid, and dense gaseous phases) at high temperatures (above 2000 °K) in experiments of short duration (millisecond to microsecond). The initial phase of the study was limited to millisecond measurement of specific heat and heat of fusion of a group of metallic elements at temperatures above 2000 °K.

An apparatus and related electrical and electronic circuitry were designed and constructed for this determination. Preliminary experiments were conducted to understand some of the high-voltage, fast-transient characteristics of the electrical equipment. Exploratory results of the research on photoelectric and photographic techniques for the measurement of temperature in the range 2000 to 4000 °K with time resolution of less than one millisecond were obtained. Investigations are under way to extend this to the microsecond time domain.

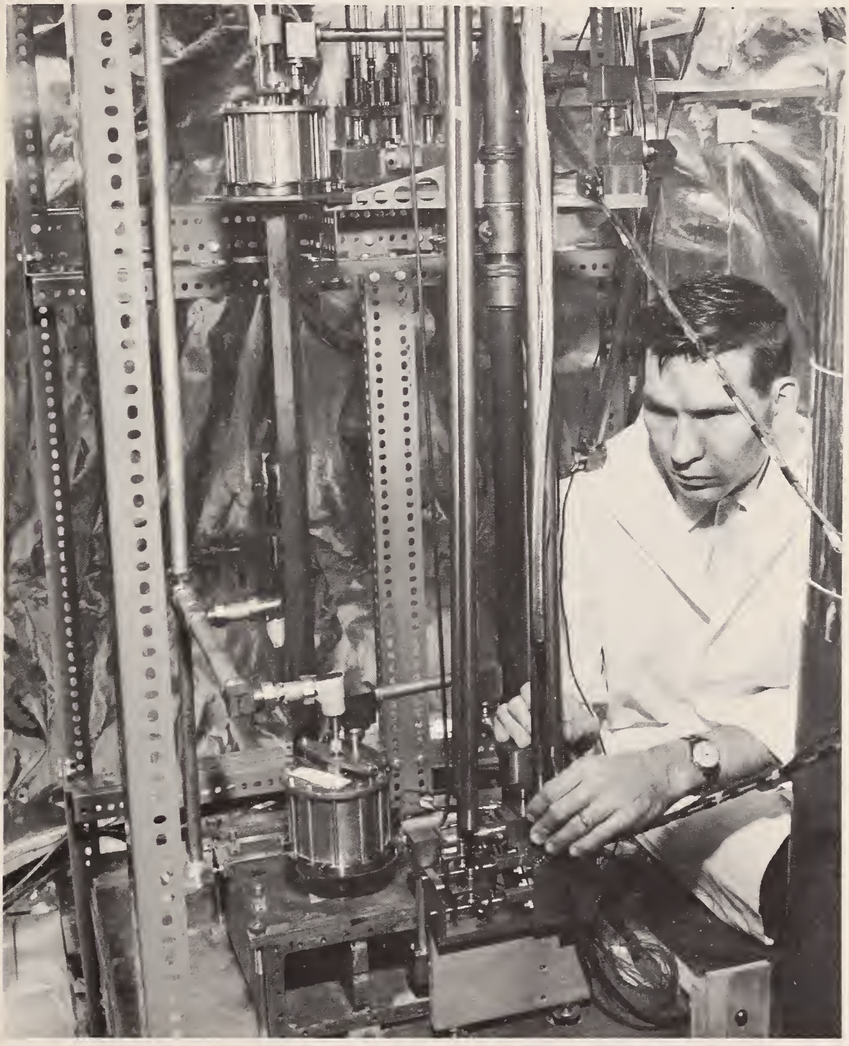
New Spectroradiometer. A spectroradiometer for spectral radiance calibrations was developed with the joint support of the National Aeronautics and Space Administration. This new instrument extends the range of wavelengths covered (2500 to 25000 angstroms (Å)) down to 2000 Å, and reduces the uncertainties of previous calibrations (about 8 percent at shorter wavelengths and 3 percent at longer wavelengths) by about one-fifth.

The spectroradiometer contains a grating-prism double monochromator, a quartz-window multi-alkali halide cathode photomultiplier tube, a stable high-temperature blackbody, a specially selected vacuum tungsten strip lamp, associated electrical equipment, and means to orient precisely and aline optically the radiation sources and to depolarize the instrument. The spectroradiometer is also an accurate photoelectric pyrometer and is calibrated at about 6500 Å in terms of the International Practical Temperature Scale by using a gold point blackbody and a recently developed multiple beam splitter.

The high-temperature blackbody is a graphite tube heated electrically in an argon atmosphere, operating routinely at temperatures up to 2600 °C and for short periods at temperatures as high as 3000 °C. The temperature of the blackbody can be controlled so that variations in the blackbody radiation are less than 0.2 percent. The blackbody's quality and uniformity of temperature were determined with special techniques.

At a specified wavelength, the spectral radiance of a test source operating at a given condition is obtained by adjusting the blackbody's temperature so that its spectral radiance is equal, as indicated by the spectroradiometer, to that of the test source. The blackbody temperature is measured by the spectroradiometer, and the spectral radiance of the blackbody at the given wavelength is determined from Planck's radiation law as equal to the spectral radiance of the test source. Current estimates are that spectral radiance can be determined with an accuracy ranging from about 0.3 percent at 8000 Å to about 1.5 percent at 2100 Å.

Precision Manometer. The advancing designs and techniques employed in revisions of the Bureau's precision mercury manometer have made it an outstandingly accurate instrument during most of its 35-year existence. With a new mercury-level detection system, pressure is measured with the highest accuracy so far attained. The location of each meniscus with respect to the lip of the cup is accurately determined by the capacitance between the



NBS precision mercury manometer, whose accuracy has been increased to within a few parts per million, is used to establish the standard atmosphere required for resistance thermometer calibrations and for constant volume gas thermometer determination of the Kelvin Scale. **(See page 73)**

crown of the meniscus and a plate and guard above it. The three-lead capacitance bridge was designed to be used with the mercury at ground potential.

The height of the mercury column is established by gage blocks on which the upper cell rests. All surfaces above the base which establish the vertical position of the mercury menisci and capacitance plates are optically flat to obtain the height of the mercury column with high precision and accuracy.

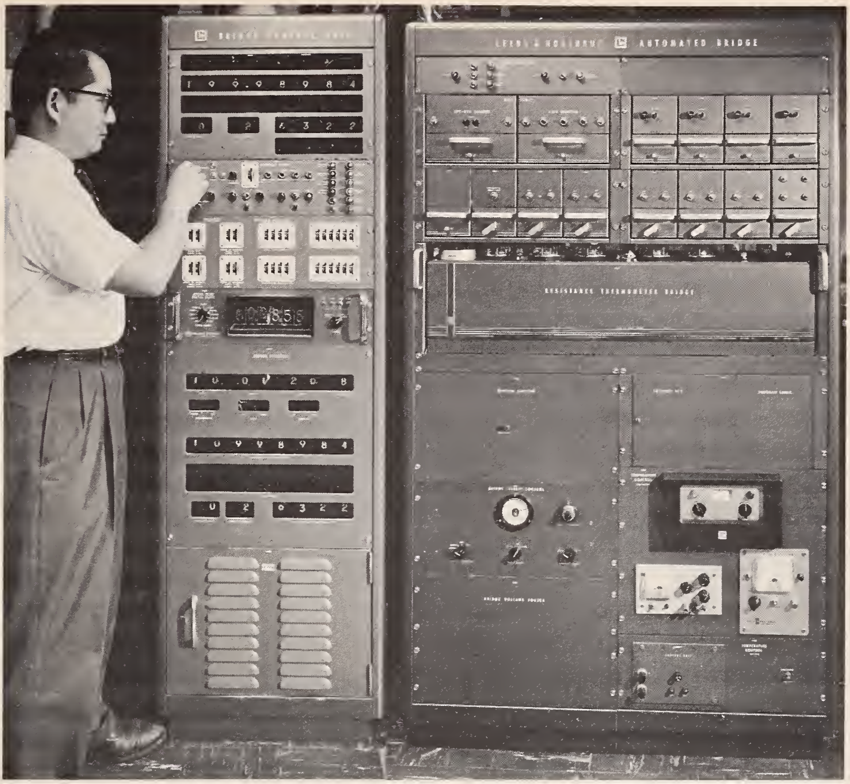
The manometer has served for many years as a standard of one atmosphere pressure for the fixed boiling points of the International Practical Temperature Scale. It has lately been improved and made more versatile for use in a gas thermometry program intended to determine the corresponding values of temperature on the International Practical Temperature Scale and the Kelvin thermodynamic scale in the range of 0.01 to 1063 °C (Int. 1948).

Pressure Transducer for Gas-Phase PVT Measurements. A rugged and highly reproducible null-type transducer was developed for accurately determining the equilibrium pressure between a Burnett PVT apparatus for gases and a counter-balancing pressure system. The transducer, closely coupled to the PVT sample volume, is used at temperatures from 0 to 200 °C over the pressure range 4 to 240 atm. The transducer consists basically of a metallic diaphragm as the pressure responsive element and a stable capacitance sensor for detecting minute deflections of the diaphragm.

For pressure imbalances less than 1 atm and transducer pressures of 1 atm or less, the reproducibility is within 9×10^{-3} mm Hg, which is the equivalent resolution of the capacitance circuitry. The maximum uncertainty in the null for transducer pressures varying from 4 to 240 atm is, respectively, 0.003 percent to 0.00004 percent. The maximum uncertainty in the constancy of the transducer volume is 7×10^{-5} cm^3 and contributes a maximum error of 0.0003 percent in the constancy of the sample PVT volume.

Developments in the Automation of Calorimetry. As a part of the Bureau's program to automate precise heat measurements, an automatic bridge developed according to National Bureau of Standards specifications was completed and installed. This instrument is used in accurate determinations of temperature with a platinum resistance thermometer, which is an accepted international standard for thermometry.

Not only does the automatic bridge release a scientist from routine measurements, but its operation is usually more accurate and faster than conventional manual operation, making possible experiments that otherwise would be too difficult. Measurements can be made with a precision of 0.00001 ohm (usually equivalent to 0.0001 °C) on a resistance as large as 500 ohms. The time required for the bridge to make a measurement decision varies from 0.2 to 3 seconds, depending on the precision required. The bridge is used to measure a varying resistance, a situation that occurs frequently in heat measurements where temperature is changing. According



Automatic bridge for temperature measurements using platinum resistance thermometers. The bridge continuously and automatically displays the readings, and transfers selected readings to a buffer storage for recording on punched cards or tapes. (Developed and built by Leeds & Northrop to NBS specifications.) **(See page 74)**

to a preset program, the measured resistance values are displayed visually in ohms and may be recorded on punched cards or tape for use with a computer, avoiding human errors in recording. The time of the measurement as determined by a standard clock is recorded also.

The automatic bridge has been designed with considerable flexibility in the logic of operation so that it can be applied to many other problems involving precise resistance measurements.

Low-Temperature Scale Improved by Correlation with NBS Data. The Thermodynamic Temperature Scale is the accepted "ideal" scale describing the behavior and properties of matter. The accepted practical scale is the International Practical Temperature Scale (IPTS), which is based on a number of fixed temperatures together with specific formulas for interpolating among these fixed temperatures. The interpolation formulas and the values of the fixed temperatures are so chosen that the IPTS will be as nearly as possible like the ideal Thermodynamic Scale. In temperature ranges where materials do not undergo transitions, the property of heat capacity is considered a "smooth" function of the Thermodynamic Scale. It is possible, therefore, to use precise heat-capacity data to check the interpolation formulas used in the temperature scales.

Precise NBS heat capacity data in the range 10 to 300 °K were correlated with the IPTS above 90 °K and with the NBS Provisional Temperature Scale below 90 °K, where there is no international scale. Both scales departed significantly from the Thermodynamic Scale, especially near 90 °K. NBS heat-capacity data as a function of the resistance of a platinum resistance thermometer were used to derive interpolating functions for temperature scales which are believed to give better agreement with the Thermodynamic Scale.

New Low-Temperature Calibrations. A facility providing calibrations from 2 to 5 °K was opened. The calibrations can be made every 0.100 °K against a group of germanium resistance thermometers that have been calibrated by reference to the T_{58} 1958 helium-4 vapor pressure scale of temperature. Years of experience have shown that germanium resistors are especially suitable for thermometry in this temperature region.

No facility has existed for the temperature range between 5 and 10 °K. When some time ago the Bureau undertook the development of a new method of obtaining absolute temperature in this low range, the most promising instrument was an acoustical thermometer. Absolute temperature would be determined from a measurement with this instrument of the speed of sound in helium gas. Expectations for the acoustical thermometer have been realized, and establishment of a calibration facility from 4 to 20 °K is planned for late 1964.

Thermal Conductivity at Low Temperatures. The thermal conductivity of neodymium ethylsulfate was measured in the temperature range 0.02 to 0.05 °K using paramagnetic susceptibility and gama-ray anisotropy as thermometric parameters. This work may aid in developing useful methods of temperature measurement below 0.3 °K. The thermal conductivity of paramagnetic single crystal materials at temperatures characteristic of transitions to the cooperative state is of theoretical interest.

Superconducting Semiconductors. Studies of superconductive transitions occurring at temperatures below 1 °K in certain ordinarily semiconducting materials were undertaken in cooperation with the Solid-State Physics Section (page 83). These transitions were predicted on the basis of the Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity, and during the course of the NBS work were found in a number of materials. In particular, various specimens of strontium tritanate ($SrTiO_3$) underwent such transitions at temperatures ranging from 0.03 to 0.3 °K. A critical examination of the BCS theory of superconductivity is made possible by detailed knowledge of the energy-band structure of semiconductor materials. The work was supported in part by the Advanced Research Projects Agency.

Magnetic Susceptibilities of Rare-Earth Trichlorides. Magnetic susceptibility measurements on a number of rare-earth trichlorides at liquid-helium temperature and below gave results substantially different from the known behavior of gadolinium chloride, which exhibits a ferromagnetic transition at 2.2 °K. Other compounds studied were cerium chloride, praseodymium chloride, neodymium chloride, and samarium chloride, all of which appear to become antiferromagnetic; except for neodymium chloride, however, the evidence was suggestive rather than definitive. The susceptibility of this chloride between 0.1 and 0.9 °K increased with increasing temperature; above 1.8 °K the reverse occurred. Two anomalous, extremely narrow spikes exist between these regions—one at 1.03 °K and the other at 1.75 °K. These spikes are extremely sensitive to an externally applied d–c field—a field of 50 oersteds almost completely eliminates them.

Single crystals of samarium chloride could not be grown. However, because the values are almost isotropic a polycrystalline sample was selected for study. Preliminary data obeyed the Curie law down to 1.7 °K and showed an "antiferromagnetic" departure below this point.

Neutron Scattering From Oriented ^{165}Ho Nuclei. The Bureau's ^{3}He cryostat was transported to the Oak Ridge National Laboratory for a joint experiment by NBS and the ORNL Van de Graaff group. The experiment was designed to detect a possible spin-spin interaction between a target of ^{165}Ho nuclei, polarized by low temperatures and a magnetic field from a superconducting solenoid, and incident polarized neutrons of 350 keV energy produced at the Van de Graaff generator by the ^{7}Li (p,n) reaction. A very small interaction was detected.

Statistical Mechanical Calculations of Properties of Many-Body Systems. Calculations relevant to the thermodynamic and transport properties of light gases, for which quantum effects are important, were made using high-speed computers. Partly in collaboration with Los Alamos Scientific Laboratory and Rice University, the quantum-mechanical second and third virial coefficients for helium were computed. An important byproduct is increased insight into the relation of various approximation methods. As part of a continuing program using the best available theory to compute the thermodynamic properties of real gases, particularly at higher temperatures, several computer programs were developed. Some, the development of which was partially supported by the Arnold Engineering Development Center, analyze and correlate available PVT data for hydrogen and deuterium and then compute the corresponding thermodynamic properties; another, developed with the support of the Air Force Special Weapons Center, is relevant to the computation of the properties of a chemically reacting gas.

In a continuing program of basis research on the nonequilibrium behavior of microscopic systems, partially supported by the Atomic Energy Commission, new general techniques for the calculation of transport coefficients of simple fluids were developed. On this basis, the first-order correction in density to the transport coefficients (e.g., viscosity, thermal conductivity, diffusion constant) of a hard-sphere gas is being computed. In connection with this program, a review of the experimental data on transport coefficients, with particular emphasis on the critical region, was completed.

A new expression for the radial distribution function in terms of the probability density of the potential at two different points and a corresponding expression for the free energy were discovered. They were used to calculate the free energy and radial distribution function of a fully ionized plasma according to a continuum approximation. This calculation and corrections to it yielded new physical insights into previous work.

2.1.7. ATOMIC PHYSICS

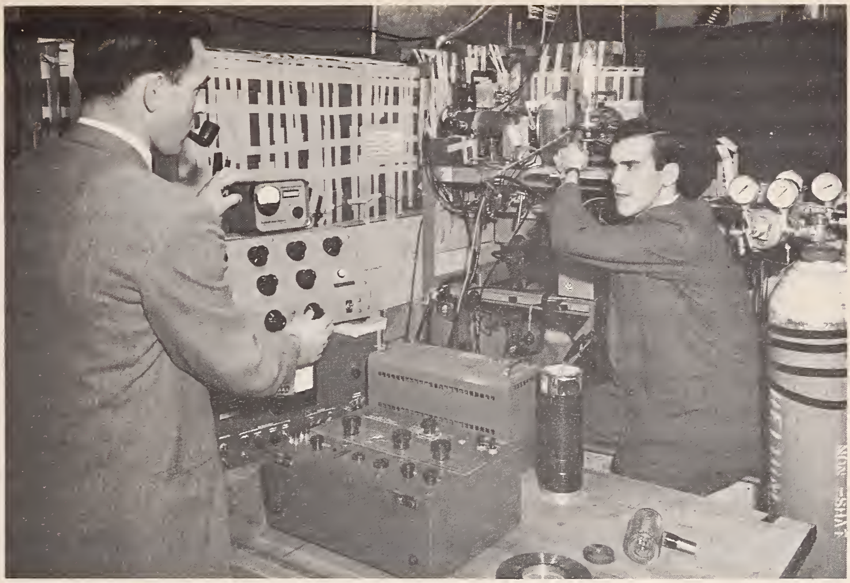
The Bureau's atomic physics program is directed toward achieving a better understanding of the properties of atoms and molecules and of their interactions with electromagnetic radiation and with other particles. Spectroscopy is a major tool in much of this work. The spectral range now available for these studies extends from the extreme ultraviolet wavelengths (100 Å) into the microwave region (1 cm). Various problems in atomic and molecular spectroscopy are under investigation, with emphasis on achieving the highest possible accuracy of measurement in order to permit the analysis of the finest spectral details. The applications of an extremely high-resolution electron scattering apparatus and of a far ultraviolet spectrometer employing synchrotron light as a source yielded important new information on highly excited states of atoms. Further insight into electronic levels in the crystalline state was provided by the program in solid-state physics.

Intermediate Energy Atomic Physics. Atoms with excitation energies from, roughly, 10 to 1,000 eV (intermediate energy) have been studied in the past only in a most fragmentary manner because of technical difficulties and lack of adequate tools of analysis. This type of excitation is normal in the high-temperature plasmas that exist in thermonuclear devices, in the upper atmosphere, and in space.

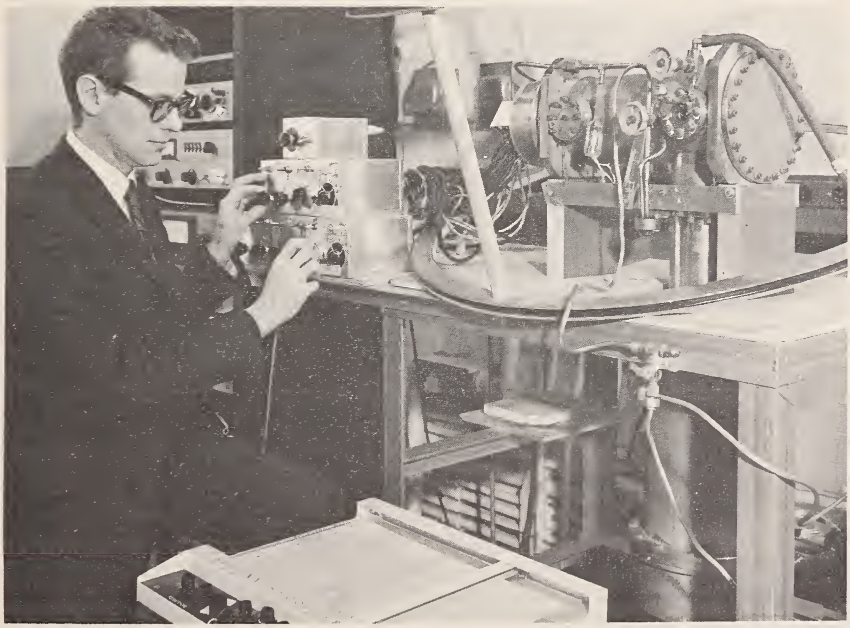
Two key analytical tools—namely, a far ultraviolet spectrometer utilizing synchrotron light as a source for the study of absorption of 20 to 200 eV photons and an ultra-high-resolution electron spectrometer for the study of 10 to 100 eV electron-atom collisions—were developed at NBS. Each of these tools provided an independent opportunity to detect, measure, and analyze atomic properties beyond the range of facilities available elsewhere.

A coordinated effort among two groups utilizing these new tools and a theoretical group has already led to observations of hundreds of new atomic levels which exhibit properties that are absent or not relevant in other energy ranges. Theory has been able to show how to identify these properties and how to relate them to quantities of more general theoretical significance (dipole and energy matrix elements).

The shape of the most prominent resonance in helium due to the two-electron excitation of the $2s2p$ $^1P^0$ state near 200 Å was studied in detail with the synchrotron light spectrometer, and was found to be in good agreement with the theoretically predicted shape. In addition to the prominent series of resonances found earlier in helium, several weaker series were observed. In the continuum absorption of the heavier rare gases (krypton



Two key analytical tools, a far-ultra violet spectrometer using synchrotron light as a source and a high resolution electron spectrometer have provided a breakthrough in detecting and measuring atomic properties.
(Above) Scientists are adjusting the 180 Mev synchrotron used as a photon source for the far ultraviolet spectrometer. The electron spectrometer (below) provides a source of monochromatic electrons in the energy range from 1 to 100 eV. These tools detect, measure, and analyze atomic properties beyond the range of facilities available elsewhere. **(See page 78)**



and xenon), states representing the excitation of innersub-shell and inner-shell electrons were identified as were those due to the simultaneous excitation of two electrons.

The synchrotron continuum was used successfully to observe high-lying molecular electronic states in both neutral oxygen and nitrogen molecules. The vibrational structures of these new states were also observed.

New complex negative ion states were discovered with the high-resolution electron spectrometer in all the rare gases, in mercury, and in molecular hydrogen, hydrogen deuteride, and deuterium, demonstrating that such states are indeed a general property of atoms and molecules. These negative ion states have an important effect on electron scattering from the parent atom or molecule, and should lead to a more fundamental understanding of low-energy elastic and inelastic collisions. Some doubly excited states to which optical transitions from the ground state are forbidden were measured by the electron scattering method.

The first excited negative ion state of helium produces a marked transparency for 19.3 eV electrons. This so-called helium window was successfully utilized both as an electron monochromator and as an electron energy analyzer.

A second generation ultra-high-resolution electron spectrometer was constructed. It incorporates angular scanning of the scattered electrons, which will permit even more detailed analysis of the mechanisms of electron scattering and aid in the fitting of the new atomic states into a consistent framework of contemporary theory.

Atomic Energy Levels. The observation and analysis of selected atomic spectra continued, with emphasis on the lanthanide group of elements. In cerium III, there are 2100 observed lines of which 75 percent were classified in a new analysis. The first regularities in praseodymium (Pr) I were found from absorption data and Zeeman patterns. The line list for Pr I is essentially complete from 2,000 to 9,000 Å.

The hyperfine structure of Pr III was studied in detail, and a new value for the magnetic moment for Pr^{141} was obtained. Work is also in progress on cerium I and II, erbium I and II, and thulium I and II.

A list of absolute *gf* values for 2000 lines of the astrophysically important iron I spectrum was prepared by reducing a compendium of relative *gf* values to the absolute scale of the NBS tables of transition probabilities.

The current revision of the 1928 edition of the solar table is nearing completion. Galley proof has been completed to 5,770 Å, and press copy to 6,700 Å. This work is being carried on in collaboration with M. Minnarert and J. Houtgast at the Utrecht Observatory (The Netherlands).

Wavelength Standards. Work to obtain high-accuracy wavelength standards in the vacuum ultraviolet region with the 35-ft vacuum spectrograph was begun. The first measurements of some neon and argon lines in the region 600 to 1,000 Å are limited in accuracy only by the errors in the best previously published wavelengths in this region. New wavelengths of neon I accurate to 0.0005 Å were obtained.

The number of interferometric thorium wavelengths was increased from 200 to 430 in the region 3,300 to 6,900 Å.

Atomic Transition Probabilities. The determinations of atomic transition probabilities for the elements of interest in plasma and astrophysics are continuing with joint support of the Advanced Research Projects Agency and the Bureau. The transition probabilities of the most important oxygen lines in the visible and near infrared were precisely measured by the wall-stabilized arc method. Because of major technical difficulties, precision determinations with this technique have been limited in the past to the lighter elements. This year the technique was extended to the study of nickel by introducing nickel carbonyl gas into the arc chamber. Even though nickel carbonyl is highly unstable and toxic, it was possible to operate the arc in a stable and reproducible condition for extended periods of time. The temperature at the arc axis was determined to be about 9000 °K, and the transition probabilities of a large number of neutral and ionized nickel lines are currently being measured. A similar experiment is under way for sulfur, where the chemically aggressive sulfur dioxide gas is employed.

The measurement of the lifetimes of several atomic states in neon using a coincidence technique produced some very accurate transition probabilities of lines of the important $3s$–$3p$ array. These transition probabilities were urgently needed for the data compilation of the first ten elements, which is in progress in the Data Center on Atomic Transition Probabilities.

Theoretical studies resulted in the extension of modified Hartree-Fock calculations to the determination of a large number of transitions in two-, three-, and four-electron atoms and ions and selected carbon and neon ions. The transition probabilities for the first ionized spectrum of nickel were calculated and preliminary comparison with experimental determinations are very satisfactory.

Infrared Spectroscopy. High-resolution studies of the infrared spectra of a number of molecules were carried out. These included various isotopic species of acetylene, allene, methane, diborane, chlorocyanogen, and others. The object of these measurements is to obtain accurate interatomic distances and angles, as well as the constants which describe the nature of the molecular vibrations. In the course of this work, a number of higher-order effects were found which influence the vibration-rotation spectrum. Such effects are of considerable importance in the theory of molecular vibrations.

A scanning interferometer was placed in operation which permits spectra to be recorded at wavelengths as great as 500 microns. This instrument has already been used to study the far infrared absorption spectra of several liquids.

Microwave Spectroscopy. Encouraging progress was made in the very difficult task of observing microwave spectra of highly reactive or short-lived molecular species. Microwave studies were made on several high-temperature systems, and detailed information concerning interatomic distances, electric dipole moments, and quadrupole coupling constants was obtained on molecules such as the aluminum monohalides. Apparatus was constructed which permits the measurement of microwave spectra of free radicals and other transient species produced in chemical reactions. The spectrum of the SO radical was detected in the reaction of oxygen atoms with various sulfur-containing compounds. This spectrum was analyzed to give accurate molecular contants for SO.

Experimental Atomic Collisions. A new instrument for the study of the photodetachment of negative ions was completed. A photon beam intercepts a negative ion beam and the rate of removal of electrons from the negative ions is determined as a function of incident photon energy. The ions can be selected with 10 times greater resolution than previously available in such experiments, allowing the study of more complex negative ions. Initial priority will be given to negative ions of importance in the upper atmosphere.

Electron Scattering in Solids and Liquids. A refined technique of Kikuchi-line diffraction with 80-keV electrons was evolved. The technique gives direct measurements of elastic scattering amplitudes for carbon and silicon atoms, in the small-scattering-angle region beween 10^{-2} and 10^{-1} radian. The method utilizes a conventional electron microscope with a tiny

High-resolution infrared spectrometer used to obtain accurate interatomic distances and bonding angles, as well as the physical constants which describe the nature of molecular vibrations. **(See page 81)**

perfect single crystal of diamond or silicon as the optical resolving element for an electron beam some 20 microns in diameter. Electron lenses magnify the Kikuchi diffraction pattern, giving detailed high angular resolution of the lines from Bragg reflections. The widths of these lines, in turn, show systematic agreement with the scattering amplitudes of these light elements as calculated from the Born scattering approximation.

The quantities thus measured are of basic interest in the theory of electron scattering, as well as being useful parameters for electron microscopy. The technique shows promise for extension to higher energies (1 to 1.5 MeV) on currently active high-voltage microscopes.

Measurements were begun of the energy losses of 10 keV electrons in liquid metals, complementing past NBS investigations of electron energy losses in solids and more recently of energy losses in gases. The characteristic loss spectrum of liquid aluminum was found to be very similar to that of solid aluminum, as frozen from the liquid, with differences attributable to density changes.

A liquid metal specimen drop was used in obtaining an atomically smooth surface and then in retaining it on solidification. Large differences were found between the scattering characteristics of smooth solid aluminum surfaces and the comparatively rough surfaces formed generally by evaporation of aluminum. For various electron scatering angles, and hence average depths of penetration, it was possible to deduce the distribution of electron paths in the sample.

The determination of the complex dielectric constant of materials in the far ultraviolet region (10 to 25 eV photon energy) from electron scattering data was carried out for aluminum and polystyrene. This method extends the spectral range for which the dielectric constant can now be determined. Sums of optical oscillator strengths were calculated for these materials.

Field-Ion Microscopy. The field-ion microscope is capable of resolving individual atoms both singly and when arranged in crystallographic planes. This instrument was recently employed to study the mechanism of the condensation of thermal tungsten atoms on a low-temperature tungsten surface.

An atomically perfect tungsten surface was prepared and then tungsten atoms were evaporated onto the surface to a depth of about a monolayer. By increasing the field at the tungsten surface it was possible to tear off the condensed atoms a few at a time until the surface was again clean. A comparison of successive photographs of the surface during the stepwise desorption of the condensed atoms showed that the atoms were deposited in small piles. It was tentatively concluded that the tungsten atoms stick at the first site they encounter on the surface. Monte Carlo and statisical calculations based on an idealized model verified this conclusion.

Solid-State Physics. In collaboration with the Cryogenic Physics Section (see p. 76) experiments were performed which established the occurrence of superconductivity in strontium titanate. This phenomenon was predicted from theoretical and experimental work of the Solid-State Physics Section, the Cryogenic Physics Section, and workers at the Bell Telephone Laboratories, Murray Hill, N. J. The effect was measured both electrically (resistance) and magnetically (susceptibility) at temperatures reached by adiabatic demagnetization. Considerable effort was directed toward a study of this effect and its dependence on conduction, electron concentration, stress, and crystal treatment. Other semiconducting materials are also being examined for superconductivity.

A theoretical investigation of the electronic energy bands of strontium titanate was completed. The detailed picture of the energy bands obtained is in substantial agreement with the results of transport measurements, e.g., conductivity, Hall, and Seeback effects of doped and reduced strontium titanate made over the range of 4.2 to 300 °K. The results are significant for the theory of superconductivity in this semiconductor, as well as for an understanding of the semiconducting properties. Analysis on transport properties of rutile, particularly the Hall coefficient anisotropy, support the hypothesis of multiple conduction bands. This explanation is consistent with theoretical band structure calculations.

A nuclear magnetic resonance study of potassium azide (KN_3) was completed and the quadrupole coupling tensors for all of the nitrogen sites in the crystal were determined. Frequency shifts of the fluorine and rubidium nuclei in the antiferromagnetic compound $RbMnF_3$ were observed and related to the covalent bonding of the crystal.

The study of impurities in rutile by paramagnetic resonance was continued and led to the observation that tungsten can be substituted for titanium. Hyperfine and superhyperfine structure lines were identified. The experiments utilized the high permittivity rutile sample as its own microwave cavity.

Photoconductive studies on cadmium sulfide (CdS) at wavelengths near the absorption edge resulted in observation of quenching and enhancement peaks which are identified with exciton and interband transitions. A precise measurement of the temperature dependence of the bandgap was obtained through this technique.

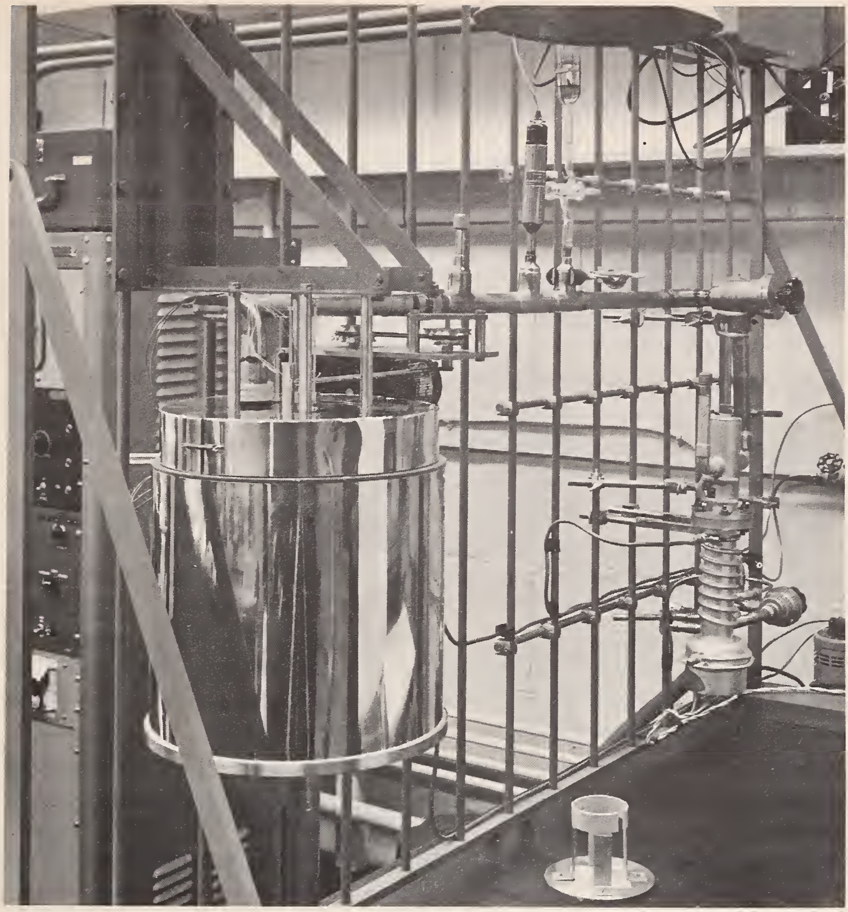
Optical absorption studies were performed on doubly ionized cobalt (Co^{2+}) ions in manganese fluoride. The spectrum was interpreted in terms of energy levels of the cobalt ion as modified by the local anisotropic crystal fields.

Color centers in magnesium fluoride were produced by exposure to x rays and electron bombardment. Optical bleaching and polarization studies are in progress.

2.1.8. PHYSICAL CHEMISTRY

The Bureau conducts an extensive program of experimental and theoretical research in physical chemistry. Integrated with this program are activities directed toward the development of new instrumental techniques and the compilation of critically evaluated fundamental data.

The primary research objective is a better understanding of the detailed molecular basis of macroscopic chemical properties and processes. Atten-



New platinum-lined adiabatic solution calorimeter makes possible the measurement of the heat of solution of refractory materials by corrosive solvents. The elaborate automatic control system for the adiabatic shield permits the calorimeter to operate with high precision at temperatures up to 100 °C. **(See page 85)**

tion is focused on two fields: (1) molecular structure, including structure of short-lived reactive species; and (2) the kinetics of elementary reactions, including reactions of neutral and ionic species, and interactions of gases with well-characterized surfaces. Supporting theoretical work is carried out on the calculation of molecular structure and energy levels, on energy transfer in molecular collisions, and on transport phenomena.

Thermochemistry. Construction and preliminary testing of a new platinum-lined adiabatic solution calorimeter was completed. This instrument, together with its energy- and temperature-measurement system, was designed to measure the heat of solution of refractory materials by corrosive solvents such as aqueous hydrofluoric acid. An automatic control system for the adiabatic shield permits operation of the calorimeter with high precision at temperatures up to 100° C, thus enabling measurements of many reactions that are too slow for calorimetry at room temperature.

A publication summarizing the available thermochemical data on aqueous univalent electrolytic solutions was prepared. It contains an analysis of all the available data on the heat capacities and heats of dilution and solution of a number of acids, bases, and salts. It also presents, in tabular form, values of the heats of solution at 25° C and the apparent heat capacities and apparent relative heat contents (as functions of concentration) of more than 60 different substances.

Surface Chemistry. Carbon monoxide on niobium was studied with a field emission microscope operated at liquid helium temperature. The absence of surface migration from the chemisorbed layer was ascribed to the existence of both a weak and a strong binding state. The weak state desorbs before migration, and the strongly bound state desorbs at higher temperatures. Molecular clustering, which mottled the field emission pattern by local field enhancement, appears to be related to surface defects of the niobium emitter.

Field emitters with a prescribed orientation were fabricated from single crystals of tungsten by means of a spark erosion technique. Adsorption studies on these emitters aid in evaluating the averaging process effect on work function determinations.

Flash desorption of carbon monoxide from single crystal ribbons of tungsten showed that the low energy state of chemisorbed carbon monoxide has a higher population density than the higher energy state on the more closely packed tungsten planes.

Infrared spectroscopy was used to investigate the matrix isolation of free radical species. The infrared spectra of matrix isolated HO_2, CF_2, and other species were obtained for the first time. The assignment of fundamental vibration frequencies led, in some cases, to an evaluation of the configuration of free radical species.

Chemical reactions in the 77 to 90 °K range between atomic hydrogen and condensed olefins were observed. After establishing the mechanism of the process, the investigators found that the disproportionation-combination reactions of hydrogen with *s*-butyl radicals could be followed in great detail. Bond strengths in various hydrocarbon free radicals were evaluated by observation of the rate of atomic hydrogen addition to each end of the olefin double bond. An apparatus was devised for measuring the rate constant of atomic hydrogen addition to a condensed olefin.

Isotope Effects. Isotope effects (differences in the behavior of isotopically labeled and nonlabeled molecules) are being used to test and extend current theories of reaction mechanisms. Study of these effects in the oxidations of normal and tritium-labeled aldoses led to a clarification of the reactions of aldoses with bromine and with chlorites. Solvent isotope effects for D-glucose and D-fructose in water and deuterium oxide showed conclusively that the so-called alpha-beta pyranose interconversions and the pyranose-furanose interconversions take place by similar acid- and base-catalyzed mechanisms.

Stereochemistry and Structure. A new sugar, 7-acetamido-7-deoxy-L-galacto-heptopyranose, was synthesized and its structure established. The sugar exhibits mutarotation and shows marked similarity to the structurally related sugars, D-fructose and perseulose.

It was found that the *bis* (phenylhydrazino) derivatives of triones exist in two modifications, one yellow, one red. Ultraviolet, infrared, and nuclear magnetic resonance studies showed that the yellow form had the conventional phenylhydrazone structure, and the red form, an unusual hybrid hydrazone-azo structure in which the imino hydrogen is united in a pseudo-aromatic ring.

Air Pollution. Under the sponsorship of the U.S. Public Health Service, a critical review was prepared on the oxidation of hydrocarbons that are commonly discharged into the atmosphere. Methods were devised to study the interaction of the hydrocarbons with oxygen, nitrogen oxides, and other atmospheric constituents. It was observed that photochemical oxidation of certain polycyclic aromatic hydrocarbons takes place during thin-layer chromatography. This observation led to the study of the oxidation of the hydrocarbons adsorbed on particulate matter. At least 10 products were obtained by photochemical oxidation of pyrene adsorbed on silica gel and on alumina.

Aldehydes and ketones are regarded as important air pollutants; hence, their photochemical behavior in the presence of oxygen is also being studied. The interplay of the effects of energy transfer, phosphorescence, fluorescence, and decomposition was investigated for systems which involve *n*-butyraldehyde, acetone, biacetyl and other carbonyl compounds.

Molecular Spectroscopy. As part of a broad effort to investigate the physical and chemical behavior of molecules in crystalline environments at low temperatures, studies of photodecompositions, molecular motions, and fluorine reactions are underway. The flash photolysis of molecules trapped in solid argon near 4 °K was successfully carried out in research supported by the Atomic Energy Commission. A new type of end-on flash tube was developed that is capable of emitting 10^{19} photons over a broad spectral range in a single 30-microsecond pulse.

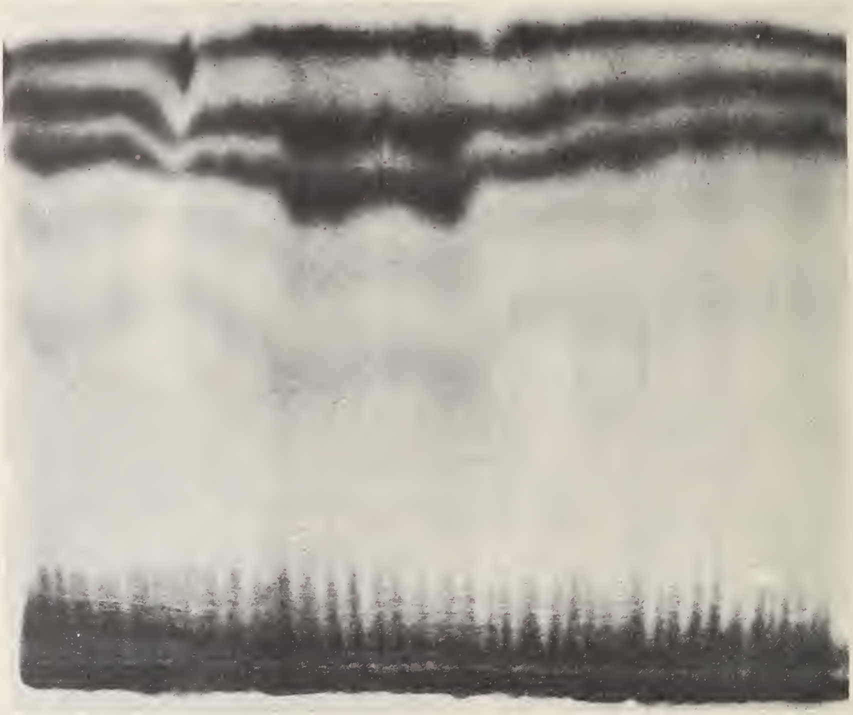
Experiments on molecular motions and interactions at low temperatures showed that carbon monoxide molecules isolated in solid argon are capable of rotational motion even at 4 °K. In a parallel study the effects of molecular perturbations in quenching the rotation of hydrogen chloride molecules were demonstrated.

In research supported by the Advanced Research Projects Agency (ARPA), the spectra and reactions of nitrogen-fluorine compounds were studied at low temperatures in noble-gas matrices. In related high-temperature studies, the electronic absorption spectrum of yttrium monofluoride was obtained and its vibrational and rotational constants were established. In other ARPA-supported work, the bent configuration of the high-temperature species Al_2O was deduced from an analysis of its infrared matrix spectrum.

Shock-Wave Studies of Unimolecular Reactions. Continuing investigation of a single-pulse shock-wave heating technique for the study of fast chemical reactions resulted in a new method for measuring the relative rates of two reactions. In this method, two compounds are decomposed in the same reflected shock, and the relative decomposition rates are determined from the relative extent of unimolecular decomposition.

In these studies, the decomposition of isopropyl bromide to hydrogen bromide and propylene was used as a "standard" reaction, because its rate is considered well established, and the rates of other unimolecular reactions were referred to this standard rate. The relative decomposition rates of a variety of alkyl halides thus obtained showed that the technique affords a significant increase in the precision of shock tube kinetic studies. For example, relative activation energies could be obtained to about 200 cal/mole.

Diffusion Coefficients Determined. As part of a fundamental investigation of the important processes occurring in gas chromatography, an accurate technique was devised for determining binary gaseous diffusion coefficients to a precision of 0.5 percent over a temperature range of from 77 to 373 °K. In this technique, the spread of a Gaussian concentration peak of one component in a carrier gas (the second component) is measured as the carrier gas flows through a long tube. Detectors stationed along the



As part of the U.S. Public Health Service program, NBS is developing methods to measure accurately and determine the interactions of the constituents of polluted air. The chromatogram shows the separation of products from photochemical oxidation of pyrene, one of the important pollutants. **(See page 87)**

tube record the change in peak shape as a function of time and distance. Measurements thus far made on oxygen, nitrogen, argon, neon, and krypton diffusing in helium show good agreement with published data obtained by other methods.

Mass Spectrometry. A mass spectrometer was built to study atomic and molecular photoionization processes out to an energy of 20 eV. In investigations of rare gases, and hydrogen, acetylene, and benzene, and their deuterated analogs with this device, precise information was obtained on ionization potentials, isotopic effects on molecular ionization potentials, and on the location and importance of autoionizing levels in atomic and molecular systems.

An instrument that permits direct observation of individual molecular ionization events produced by medium energy (1 keV) electrons was also constructed. The device was used to determine the relative amount of various charged species produced by electron impact, and to study the fragmentation of multiple charged molecular species. In studies carried out on carbon dioxide, methane, carbon tetrafluoride, and propylene, a number of distinct processes were found to occur. These processes involve the instantaneous decomposition of an ionized molecule into two charged fragments traveling with several electron volts of kinetic energy.

Mass Spectrometric Reaction Kinetics. A mass spectrometric method, developed to investigate the rates of very fast atomic reactions, was used to study the reactions of nitrogen oxides with atomic oxygen. With the use of oxygen 18 isotopes, it was found possible for the first time to determine the rates of a number of oxygen atom isotope exchange reactions with molecular oxygen, nitric oxide, and nitrogen dioxide.

Vacuum Ultraviolet Photochemistry. The fragmentation mechanism of a simple molecule upon absorption of a large quantum of energy just below the ionization potential is being studied by vacuum ultraviolet photochemistry. For the first time, successful experiments were conducted in high-temperature (up to 400 °C) vacuum ultraviolet photolysis of ethane in the 1,200-Å wavelength region. The photolysis of ethane in solution in liquid nitrogen was also accomplished at 1,470 Å and 1,236 Å. During the year, and argon resonance lamp of high chromatic purity (1,048 Å and 1,067 Å) and of moderately high intensity ($>10^{14}$ quanta/sec) was developed for use in these experiments.

Radiation Chemistry. The fragmentation mechanism of a molecule receiving energy in excess of its ionization potential and the resulting fragments are studied by radiation chemistry. The technique was used to measure the cross sections or rate constants of hydride transfer, charge transfer, and proton transfer reactions. The effect of an applied field upon gas-phase radiolysis was also studied. This technique provides an independent measure of the relative contributions of neutral excited species and ionic species to the total chemistry.

2.1.9. LABORATORY ASTROPHYSICS

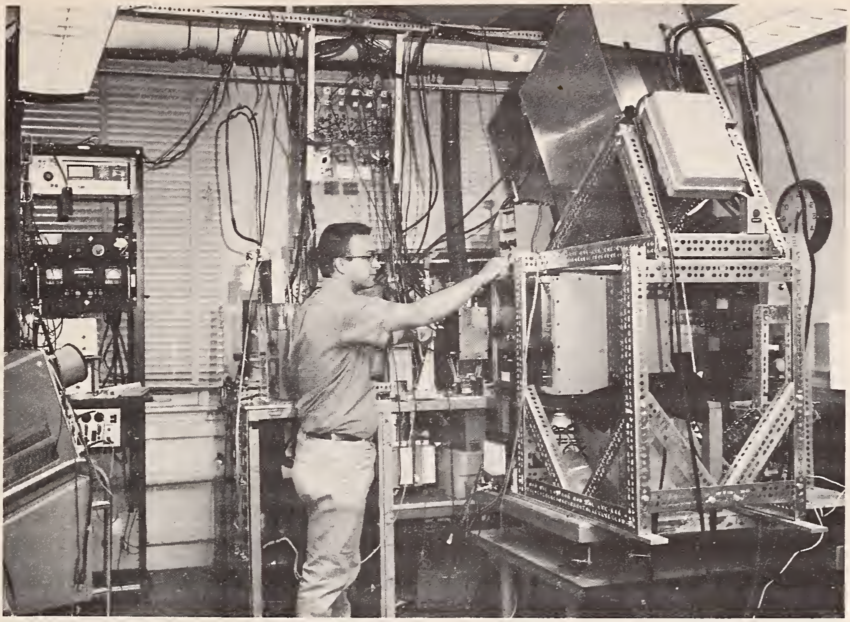
The Joint Institute for Laboratory Astrophysics (JILA) at Boulder, Colo., is a collaborative effort of the National Bureau of Standards and the University of Colorado. The purpose of the Institute is to provide a center for advanced research and training in physics related to measurements of the properties of very hot gases. The participants, in addition to graduate students, are members of the NBS Laboratory Astrophysics Division, members of the science and engineering faculties of the University, and eminent scientists participating on one-year appointments under the NBS-sponsored Visiting Scientist Program. Research areas include astrophysics, atomic physics, aerodynamics, and statistical mechanics. During the past year very significant collaborative scientific efforts were developed among members of all of the groups participating in JILA.

The activities of the NBS Laboratory Astrophysics Division have been concentrated in the study of the physics of stellar atmospheres, the study of the physics of atomic collisions, and the study of atomic structure and interactions by special optical techniques, such as those using lasers.

Participating in the support of the research of the NBS Group in JILA are the Atomic Energy Commission, the Office of Naval Research, the Army Research Office (Durham), Sacramento Peak Observatory of the Air Force Cambridge Research Laboratories, and the National Aeronautics and Space Administration. Virtually all of the work reported here is in collaboration with students and staff of the University of Colorado. In addition there are joint research programs with the Sacramento Peak Observatory, the Nice Observatory, the University of Hawaii Geophysical Institute, and the High Altitude Observatory.

Astrophysics. During the past year, the astrophysics program within JILA continued to emphasize the development of the analytical methodology for quantitative spectroscopic measurements in hot gases. Programs in solar astrophysics were aimed at testing these diagnostic techniques in astronomical observations—for astronomy offers the most extensive laboratory available. The primary effort is attempting by this means to understand solar features more satisfactorily. The program of collaborative investigation of aerodynamical phenomena in the solar atmosphere by aerodynamicists and astrophysicists continued, and the same kind of systematic investigations into stellar atmospheres began.

Spectroscopic Diagnostics. Work on spectroscopic diagnostics progressed in two main directions: the development of broader and more precise methods for solving the radiative transfer equation over the entire line profile to give a more complete picture of the extent of non-LTE (local thermodynamic equilibrium) effects both within the gaseous ensemble and across the spectral line; and the study of the problem of local and nonlocal effects on the state of a gaseous ensemble, particularly as it affects the diagnostic problem. In the first direction, parallel progress was made by Visiting Fellows of JILA in collaboration with the Harvard-Smithsonian group and



Graduate student studies cross sections for proton excitation of gases important in the theory of the aurora. This work is part of the JILA program sponsored jointly by NBS and the University of Colorado. **(See page 92)**

by members of the Paris Observatory group with whom JILA is closely associated.

Solar Studies. In collaboration with the Sacramento Peak (Sunspot, N. Mex.) and High Altitude (Boulder, Colo.) Observatories, work continued on the compilation of data taken during the 1962 eclipse. A prototype photoelectric observation of the continuum on either side of the Balmer limit was carried out during the 1963 eclipse in preparation for more extensive observation of the 1965 eclipse. In collaboration with the Sacramento Peak Observatory, investigation continued of the mass and energy requirements to maintain the coronal loop prominence system. A program of non-LTE abundance investigations was started in collaboration with the Paris Observatory group. Detailed studies of individual lines in the solar spectrum continue.

JILA is engaged in plans for two scientific expeditions to the May 1965 total eclipse of the sun in the South Pacific. The project is supported in part by the Sacramento Peak Observatory and by NASA. One of the expeditions is in collaboration with St. Johns Observatory, New Zealand, and the University of Pennsylvania Department of Astronomy. Two similar photoelectric spectrographic instruments to be used during the eclipse are being constructed. The scientific objectives are based on the very precise height resolution obtainable at an eclipse and, to a lesser (but real) extent, on the low background sky emission. The spectral regions to be covered involve continuum measurements to the red and blue of the Balmer and Paschen discontinuities, i.e., the helium lines at wavelengths 5,876, 6,678, and 4,686 Å, the coronal red and green lines, and continuum measurements at 1.6 and 2.25 μ. The chosen spectral regions span a range of excitation in the chromosphere in order to permit analysis using data which will give most sensitive indications of temperature changes. In addition, this type of experiment will also yield (slitless) spectral data at the extreme edge of the sun on a number of wavelength regions.

Stellar Atmosphere Studies. The investigation of sources of stellar instabilities leading to aerodynamic motions continues, mainly through collaboration with the University of Colorado Departments of Physics and Astrophysics and Aerospace Engineering Sciences. Efforts are presently concentrated on the study of variable stars generally and the Cepheids particularly; the latter project, in collaboration with the staff at Los Alamos, is aimed at mapping the region of pulsational instability. Preparations were started for a 1965 symposium on this subject, with the secretariat at JILA. The symposium will be sponsored by the International Astronomical Union and the International Union of Theoretical and Applied Mechanics, and will be held in France at the Nice Observatory. Work also began on a more careful inclusion in astrophysical theory of the radiative loss from aerodynamical energy dissipation in an effort better to understand the effects on atmospheric structure. The non-LTE radiative transfer investigations mentioned in the section on *Solar Studies* are used.

The program of investigating the calcium II *H* and *K* lines in stars of a range of spectral types continued in collaboration with the Kitt Peak Observatory—University of Arizona group. Some investigations of novae and emission lines in stellar spectra were initiated in collaboration with the Paris Observatory group. The latter efforts are initially aimed at separating non-LTE and aerodynamic heating from geometrical sources for emission lines.

Under way is an investigation seeking to explain the anomalous behavior of certain rare-earth lines in the solar spectrum. These lines, which are observed in the wings of calcium *H* and *K* lines near but inside the solar limb, appear in emission relative to the local background. This study has a bearing on the question of departures from local thermodynamic equilibrium in the solar photosphere and if successful would lead to revised values of some rare-earth abundances.

Physics of Atomic Collisions. A detailed calculation was made for photodissociation of positive ions of molecular hydrogen and deuterium. Measurements of this cross section are in substantial disagreement with the calculation. An explanation of the discrepancy may lie in possible anomalous populations of the vibrational levels of the ions due to autoionization. Such effects have been indicated by work on photoionization molecular hydrogen at the NBS Washington Laboratories. This possibility is being explored and the experiment is being improved to give better accuracy for comparison. This work is supported by the Atomic Energy Commission.

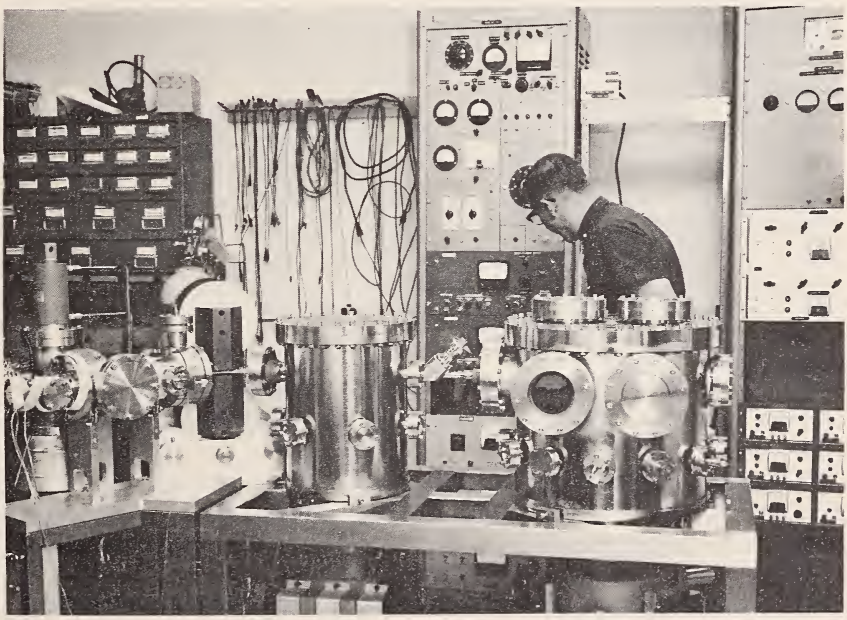
Experimental studies of the stripping by hydrogen gas of two electrons from the negative ions of hydrogen and deuterium were carried out. These relative measurements as a function of energy join smoothly to Russian work at higher energies. A surprising result, however, is that the deuterium ion cross sections are larger than the hydrogen ion cross sections when the ion velocities are the same. Other ion-molecule collisions are being investigated to see if a similar isotope effect exists.

A calculation of the free-free absorption coefficient of H– was completed using 10-parameter e–H elastic scattering wave functions. The results are more accurate than the previous values, which have been widely used by astrophysicists.

The compound (or autoionization) state energies for H– and He were evaluated by a variational method. Excellent agreement was obtained with the experimental results from NBS Washington, and new level positions were evaluated.

The mechanism of gas breakdown by means of intense laser beams is under investigation. Both classical and quantum treatments of the absorption of radiation by free electrons are being applied.

The theory of the rotational excitation of diatomic molecules by slow electron impact is being improved by an application of the method of distorted waves. The discovery of large maxima in the rotational cross sections should allow a more reliable interpretation of experiments involving swarms of electrons in diatomic gases.



This newly constructed crossed beam apparatus permits the study of the interactions of particles with those that are inherently unstable in nature. For example, it will be used to study electron and photon interactions with ions and metastable atoms. **(See page 92)**

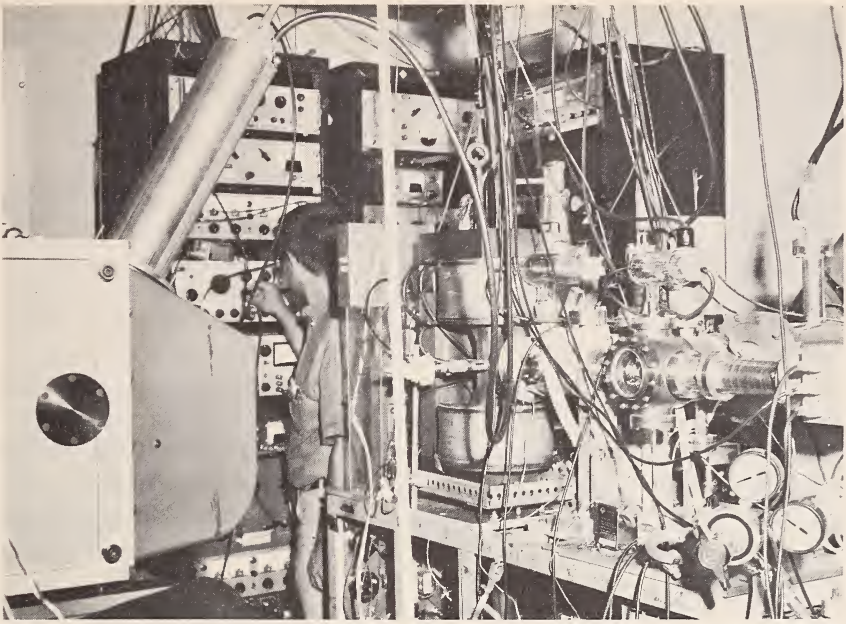
An experimental study of the excitation of radiation from hydrogen atoms by electron impact showed that the cross section for excitation of the lowest optically allowed hydrogen transition has an anomalous behavior for the lowest electron energy capable of exciting it. Apparently the cross section rises discontinuously, or nearly so, to a finite value at the threshold energy. This behavior has not been observed previously and will play a significant role in understanding the production of radiation in the solar atmosphere and in hot gases in general. The anomaly is presumably related to the permanent dipole moment of the hydrogen atom which results from the near-degeneracy of the two lowest excited states of hydrogen.

Plasma Transport Properties. A notable advance in high-precision measurement if ion mobilities in gases was substantiated with the completion of a detailed study of helium ion mobility in helium gas. The results led to a new method of measurement of ion-molecule reaction rates, and the rate of the three-body reaction of atomic helium ions to form ions of the diatomic molecule was determined to an accuracy of a few percent, which is rarely achieved in conventional chemical kinetics. The technique is now being applied to the study of ion-molecule reactions involving negative ions, in view of the importance of these reactions in ionospheric physics.

Resonance Physics. Reliable measurements of absolute oscillator strengths for resonance lines of ions are difficult to obtain by conventional techniques because of self-absorption of the resonance radiation and uncertain values of the ion density of the emitting plasma. An experimental program was initiated to measure lifetimes of ions of astrophysical interest by a technique which eliminates these difficulties: the technique involves a study of the angular distribution of resonance fluorescence as a function of applied magnetic field (Hanle effect).

Some attention was given to the factors that enhance spectral brightness of ruby Q-switch lasers with the aim of obtaining as near "single-mode" operation as feasible. This property is a necessary prerequisite for meaningful study of nonlinear optical behavior, such as stimulated Raman scattering, multiphoton absorption, and optical harmonic generation. The Stokes Raman-shifted laser output from various liquids was used to study the wavelength dependence of two-photon absorption and related nonlinear processes in anthracene crystals. In addition, some effort was invested in high-stability gas laser sources for long path interferometry and measurement of millimeter wave difference frequencies between two gas laser spectral lines.

Physical Constants. A 30-meter vacuum Fabry-Perot interferometer is being set up in an unused gold mine near Boulder, Colo. Path stability checks and a high-precision measurement of the path lengths are planned. This instrument may be used in a laser velocity-of-light measurement if it appears that the long path will lead to susbtantially higher accuracy than can be achieved in a shorter path device. Work on a possible xenon laser wavelength standard for use with the long interferometer was started, and the Lamb dip in one of the possible lines was observed.



Crossed beam apparatus for the study of interactions of light beams with ions. Current work includes photodissociation, and proton impact excitation studies. **(See page 92)**

A falling interferometer to measure the acceleration of gravity was designed. The question of a suitable release mechanism was solved and construction started.

Data Center on Atomic Collision Cross Sections. The Data Center has issued a bibliography of data on low-energy (<10 keV) electron collision cross sections. About 600 copies were distributed to research workers in the areas of atomic and plasma physics and astrophysics. At the present time, a critical review of data on electron impact ionization cross sections for atoms and diatomic molecules is being prepared.

2.1.10. RADIATION PHYSICS

The radiation physics research program of the Bureau is directed toward obtaining basic experimental and theoretical data in the areas of radiation interactions with nuclei, atoms, molecules, and bulk matter; the development of improved techniques and instruments for the detection and measurement of radiation; and the investigation, development, and improvement of radiation sources and standards.

Expanding applications of radiation in industrial processing have created a need for improved standards and dosimetry at high dose levels and at high energies. Persons conducting research on the nature of the interactions between radiation and materials are requesting more accurate cross sections. Improved accuracy in the determination of source output and absorbed dose is required by medical radiologists.

Considerable effort was devoted to preparation for the implementation of an enhanced research program that will be made possible by a new laboratory building now nearing completion. New high-intensity sources, such as the 1.5- and 4-MeV direct accelerators and the 100-MeV linear accelerator, will enable the Bureau to satisfy many of the increased requirements. The compilation and evaluation of critical data began in the areas of electromagnetic and photonuclear interactions. Programs were initiated on the investigation of low-level radioactive contamination in materials and on the calculation of energy dissipation by fast electrons and associated gamma radiation for given source and medium configurations.

Dosimetry

Cavity Chambers. Instruments used as laboratory standards for x- and gamma-ray measurements by medical institutions, research laboratories, manufacturers, atomic energy installations, the Military, and Civil Defense are calibrated using the Bureau's x-ray and gamma-ray standards. The accuracy of the measurement of the beams used in these calibrations is presently better than 2 percent. During the past year, a toal of 102 calibrations was performed.

Effects of cavity-chamber geometry on the measurements of gamma-ray beams used to calibrate secondary standard exposure meters were studied to find the corrections required for conversion of cavity-chamber measurement data to exposure units.

A collimating system for the high-exposure-rate cobalt 60 source was constructed, and the rectangular beam obtained was calibrated. The system permits calibration of instruments of ranges higher than 25 roentgens, under controlled irradiation conditions. Leakage and stem effects in condenser *R-meter* chambers used as secondary standards were studied to develop calibration procedures. Further study is needed to reconcile the measured stem effects with the differences observed between calibrations for different irradiation conditions.

Photographic Dosimetry. Studies on enhancing x- and gamma-ray responses in several photographic dosimetry emulsions included hypersensitization with certain salt baths, latensification by means of chemical treatments or post-exposures to selected narrow bands of light, special development procedures, and combinations of these. The study of special development procedures for reducing the energy dependence of dosimeter-film response to x and gamma radiation in the range from 0.025 to 1.25 MeV continued. A reduction in energy dependence by over a factor of 2 was achieved at the expense of some loss in sensitivity.

Characteristics of commercial x-ray dosimetry films exposed to photons of widely different energies were compared for processing in phenidone-thiosulfate monobaths and in x-ray and phenidone developers. For routine dosimetry applications, monobath processing has the advantages of little dependence of response on processing time and temperature and, because of lower contrast, extended useful exposure range. Difficulties due to rate dependence are more likely to occur, however, and film sensitivity is reduced.

Processes leading to solarization and other rate-dependent photographic effects were investigated. The study of the total silver content of developed photographic emulsions, concentration of silver grains, and grain structure was completed.

Solid-State Dosimetry. Comparative measurements were made to determine the sensitivity, energy dependence, and voltage dependence of the response to x rays of diffused *p-n* junction, *p-i-n* junction, and surface-barrier-type silicon radiation detector cells. Measurements were limited to energies of less than 250 keV to avoid radiation damage possibly produced in silicon by radiations of higher photon energy.

Photocurrents observed in *p-i-n* junction cells were larger and showed a smaller increase with increasing bias voltage than photocurrents measured in *p-n* junction and surface-barrier cells at the same exposure rate and with the same irradiated cell surface area. However, because of their smaller zero-voltage resistance, *p-i-n* junction cells have larger dark currents and may show a smaller photovoltaic sensitivity than cells of other types when operated with higher load resistances or under open-circuit conditions.

When either a forward or reverse voltage was applied to the commercial-type surface-barrier cells, most of them showed similar, nearly symmetrical current-voltage characteristics. This similarity apparently was due to the existence in such cells of two opposing voltage barriers which are alternately reduced or increased when a bias voltage is applied in these two different directions. Consequently, the photocurrent showed a reversal with reversing bias voltage and the photovoltaic sensitivity was negligibly small. Surface-barrier cells showing such performance charactertistics can be used only as photodiodes.

The dependence of the photocurrent on the quality of the x rays (energy dependence) was found to be similar for the three cell types investigated, and changed only slightly when moderate bias voltages were applied.

Response of Hurst Neutron Dosimeter. Recently, the fast neutron dose distribution in water from a $D(d,n)^3He$ source was measured. The energy response of the Hurst proportional counter dosimeter used in the measurements did not follow the predictions of the original paper describing the instrument. An investigation showed that an incorrect spectrum had been assumed for the recoil particles incident on the cavity. A simple corrected calculation led to much better agreement with the experimental measurements, and a more sophisticated calculation for the response of spherical and cylindical counters of this type in an isotropic field was completed.

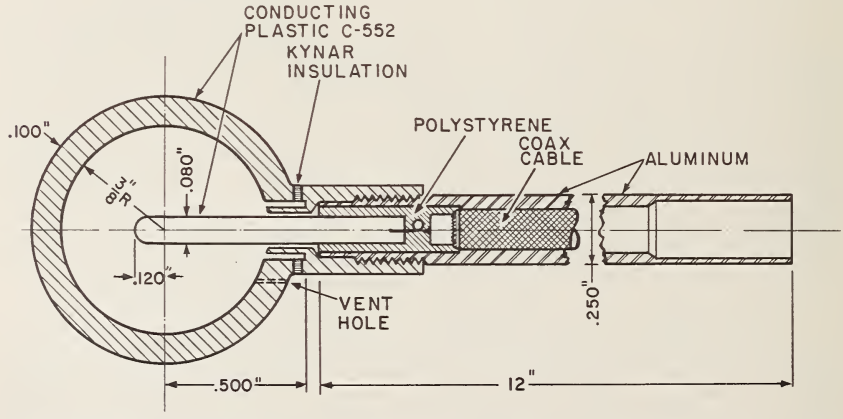
X- and Gamma-Ray Standards. Several years ago the National Bureau of Standards designed, constructed, and calibrated some ionization chamber transfer instruments for the Bureau International des Poids et Mesures (BIPM). Since that time, a number of large laboratories and clinics have expressed an interest in such instruments, and the BIPM has recommended that each national laboratory obtain its own transfer instrument so that all could be intercompared at BIPM. On the basis of this broader need, one instrument was redesigned in a cooperative program arranged with F. R. Shonka of St. Procopius College, Lisle, Ill., who contributed knowledge of conducting plastics and molding techniques.

One model of the new version, with an outer wall thickness of 2.5 mm, can be used to measure 60 to 250 kV x rays and cobalt 60 and cesium 137 gamma rays with a variation in calibration factor of about 4½ percent. Another model, with a wall thickness of 0.25 mm, can be used to measure 60 to 250 kV x rays with a variation in calibration factor of about 3 percent. For repeated calibrations, the range of calibration factors for any one quality of radiation is about 0.3 percent.

Recently a need has arisen for the calibration of instruments used by medical institutions, research laboratories, and others for the measurement of very soft x rays produced by 10 to 15 kV. Accordingly, a free-air chamber standard for the measurement of x rays produced by 10 to 60 kV was constructed. Comparison with the NBS "low" energy standard, used for measurement of x rays generated by 20 to 100 kV, in their overlapping range gave an agreement, on the average, to 0.3 percent. The estimated maximum inaccuracy is about 1 percent.

Radioactive Sources

Standards of Radioactivity. The sum of standards sold and calibrations performed exceeded 650. Radioactivity standards developed and prepared for distribution included tritiated (hydrogen 3-labeled) toluene, strontium 89, cerium 141, cesium 137-barium 137*m* (gamma-ray point source for gamma-ray spectroscopy), and americium 241. International comparisons were conducted of the radionuclides strontium-yttrium 90, americium 241, and cobalt 60 (solid sources), distributed by the Bureau International des Poids et Mesures; cesium 137-barium 137*m*, distributed by the International Atomic Energy Agency.



Cross section of NBS model of a portable ionization chamber for use in the international standardization of radiation measurements by the International Bureau of Weights and Measures. The instrument measures 60 to 250 kV x rays as well as cobalt-60 and cesium-127 gamma rays. **(See page 97)**

A new, precise method for diluting highly volatile liquids was used to prepare tritiated toluene which when compared with previously standardized tritiated water by liquid scintillation counting gave a standard deviation of 0.1 percent.

Four radiochemical procedures, suitable for the determination of actinides at the 0.1 MPC (maximum permissible concentration) level were evaluated under the low-level radioactivity program, supported partly by the Atomic Energy Commission. A new method of low-level radioisotope dilution analysis was developed and applied to cerium 144. Low-level intercomparisons of cerium 144 in spinach (sponsored by the International Atomic Energy Agency) and in radium 226 in water (sponsored by the Public Health Service) were carried out.

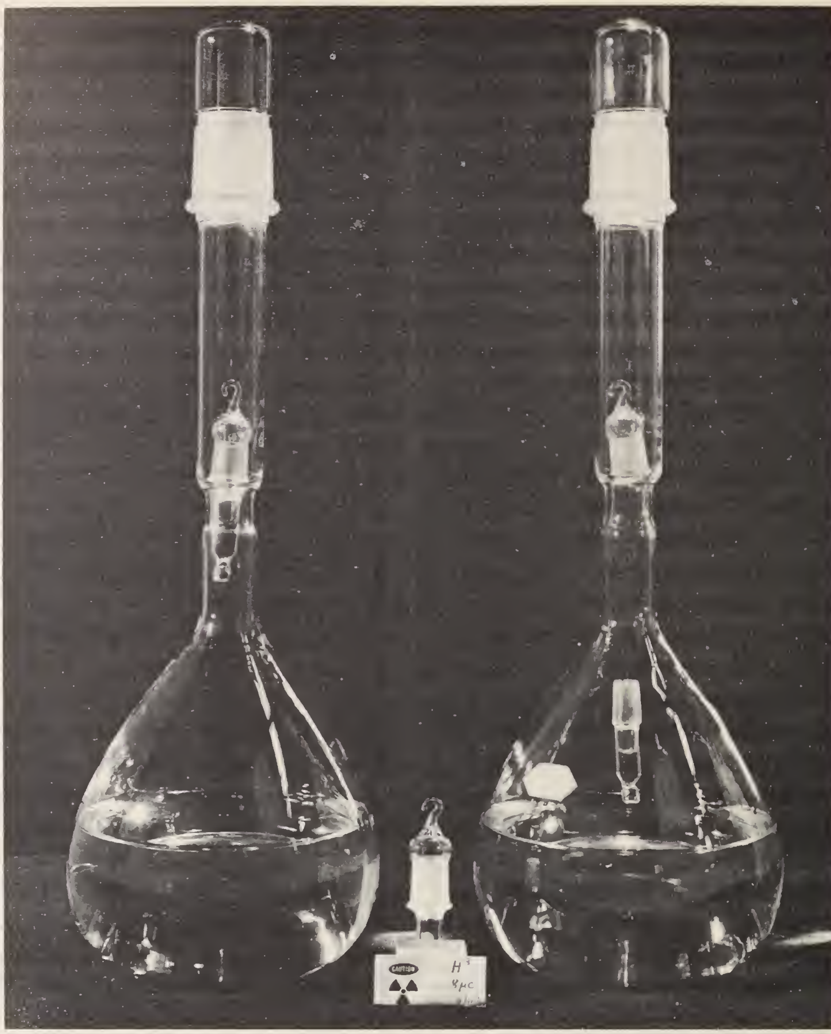
Spectrometer for Neutron Source Studies. The energy range of greatest uncertainty in the use of neutron sources as standards is below 2 MeV, where most spectrometers do not work or work poorly at best. A proton recoil spectrometer using a methane proportional counter as radiator and a silicon junction detector as the major energy detector is being developed. Preliminary results indicate that the instrument will be useful down to at least 0.5 MeV, and will exhibit the low gamma sensitivity required for spectral measurements of sources, such as the NBS standard Ra-Be(γ,n) source, having high gamma emission rates.

Radiation Interactions with Nuclei

Fast Time-of-Flight Measurements of Neutron Cross Sections. After interaction with the nucleus under study, neutrons of differing energies are separated by measuring their flight times from target to detector. With one technique (Mobley system), the neutrons are produced in bursts and the time of detection relative to the incident neutron burst is measured; with the other, a charged particle produced at the same time as the neutron is used as the time reference. A Mobley time compression magnet system installed on the Van de Graaff accelerator produced 0.8 microsecond proton pulses of about 360 microamperes. The charged particle technique was refined by improving the time resolution to about 1 microsecond and developing n-γ discrimination compatible with fast time of flight.

Nuclear Size Determinations from Coherent Neutral Meson Photoproduction. An extensive series of measurements on nuclear matter distributions by coherent π^0 photoproduction were completed for lithium, beryllium, carbon, oxygen, magnesium, aluminum, silicon, sulfur, calcium, and copper. The nuclear matter radii were determined with an accuracy of about 0.2×10^{-13} cm and agree well with nuclear size determinations by other techniques, such as elastic electron scattering.

Nuclear Theory. A dynamic theory of the nuclear collective model was developed in which the rotation-vibration model and the hydrodynamical dipole-oscillation model are unified. A coupling between the dipole oscillations and the quadrupole vibrations is introduced in the adiabatic approximation. The dipole oscillations act as a "driving force" for the quadrupole vibrations and stabilize the nucleus in a non-axially symmetric equilibrium



Flask and sample container used for the new dilution technique developed for standardizing tritiated toluene. **(See page 98)**

shape. The dipole operator is established in terms of the collective coordinates, and the gamma absorption cross section is derived.

Calculations are in progress to determine nuclear energy levels and wave functions, according to the shell model, for nuclei with atomic weights between 17 and 40. The computational difficulties are being reduced through the application of group-theoretical methods involving the group SU_3. A further test, through the study of elementary particle reactions, indicated large violation of SU_3 symmetry. This discrepancy could be accounted for by the presence of a large amount of octal symmetry braking (configuration interaction). A series of super resonances in the baryon resonance-meson systems were predicted as a result of this analysis.

Elementary Particle Theory. The role of unitary symmetry (SU_3) in the classification and description of the various elementary particles was explored in detail. A particularly successful test was developed in the form of a sum rule for the cross sections of some π^+ and K^+ initiated processes. The difficult problem of comparing reactions which involve projectiles of different incident energies and which have a varied assortment of initial and final states was solved by a two-step process. Satisfactory agreement was obtained between theory and experiment, and the assumption of unitary symmetry in strong interactions was deemed valid.

Photonuclear Cross Sections. The experimental program concentrated on measurement of the photoneutron yield cross section for light nuclei (^{10}B, ^{11}B, ^{6}Li, ^{7}Li, and ^{3}He). Although only a preliminary analysis of the data for the boron and lithium isotopes was made, there appear to be a number of previously unobserved significant and unexpected features in the cross sections. Results of this experiment will contribute to the field of photonuclear reactions. Data obtained with a neutron detector in its early stages of development already shed considerable light on the discrepancies now existing in the magnitude of the photoneutron cross section.

Detector for Photonuclear Reactions. One of the few systematic experimental studies of the response characteristics of a 4π-neutron detector of the type used throughout the world for measurements of photonuclear cross sections was completed. Preliminary analysis of the data indicated the probable source of the discrepancies that now exist in various measurements of photoneutron cross sections.

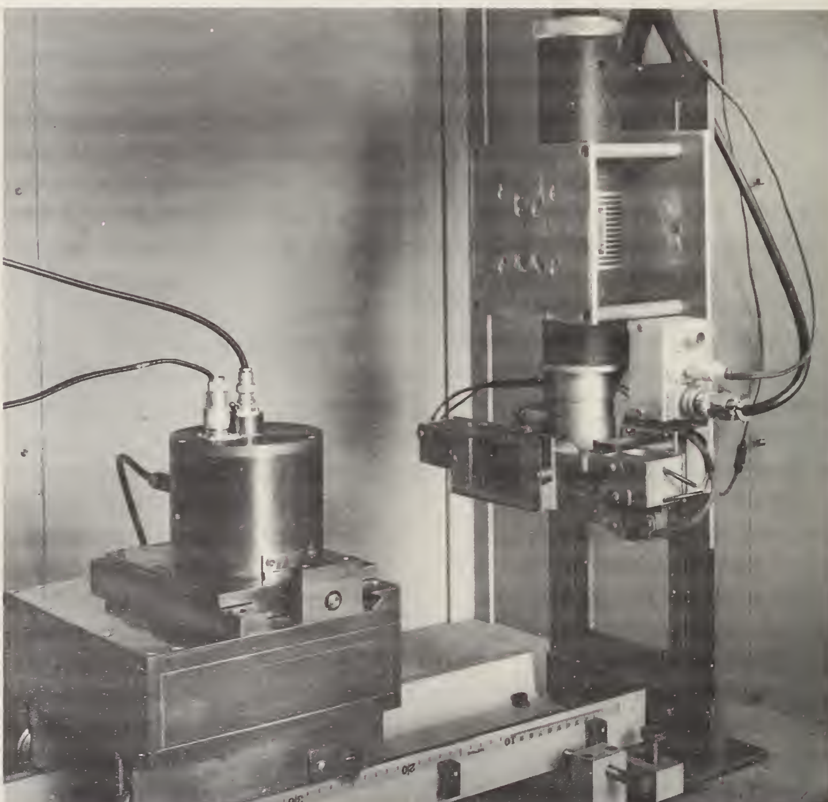
The characteristics of semiconductor radiation detectors were investigated in detail to determine their usefulness in photonuclear reaction studies. Significant technological advances were made in extending the length of silicon lithium-drift detectors. Measurement of the response of semiconductor radiation detectors as a function of temperature down to 4.2 °K resulted in the discovery of an anomaly which may have interesting thermometry applications.

Nuclear Spectroscopy. New techniques allow beta-ray spectroscopy with oriented nuclei to be accomplished with considerably higher resolution than possible heretofore. These techniques were applied to the measurement of matrix elements in two forbidden beta-ray transitions in cerium 141. Extensive calculations related the experimental results on cerium 141 with theoretical predictions based on gage invariance principles.

New Linear Accelerator. Installation of the linear accelerator (Linac) in the new Radiation Physics Laboratory at Gaithersburg, Md., began in April. Almost all major components of the accelerator are now in place, with plumbing and interwiring well under way. Various subsystems being installed include an inspection and warning system, a complex alarm, a remote TV monitoring system, a radiation monitoring system, and an intercommunication and announcing system.

Magnet Testing Program. A magnet-testing program, utilizing heavy ions produced by a 400 keV Van de Graaff accelerator to accurately simulate electrons from the linac, made possible comparison of the actual behavior of magnetic components of the beam-handling system with the predicted performance. Elements tested to date are one 45° bending magnet, one set of 4-in. quadrupole magnets, and two sets of 2.5-in. quadrupole magnets. These measurements, together with floating-wire and various magnetic field measurements, indicated substantial differences between the predicted and the actual performance of magnets. Measurements of actual magnet performance, combined with computer calculations, served to define proper locations for the magnetic elements of the beam-handling system necessary to insure required system performance.

Target Chamber Design. Target chambers were designed that can withstand the intense beam current and the high-radiation environment of the linear accelerator. The radiation field makes it necessary to avoid the use of organic materials in the chamber construction, and the beam intensity has necessitated both water cooling and target oscillation.



The NBS free-air chamber for measurement of 10 to 60 kV x rays was recently developed to calibrate instruments used by medical institutes and research laboratories. **(See page 97)**

Data-Handling System. An on-line data-handling system developed for use with the linear accelerator provides concurrent on-line processing of data from several independent experiments. Several novel devices are included to permit convenient real-time operator control of computer functions and to provide privacy of program by means of priority interrupt lines controlling the sequence of operations. A family of building blocks is being developed for the input of information. Surprisingly, the requirements of all nuclear physics experiments projected for the facility can be met with only six different blocks which feed information into the computer via a multiplex register unit. The man-machine interface is made flexible by the use of two decoding units, one for outgoing signals and one for sense-switch type information to be used in computer control. The conventional computer output devices are supplemented in this system by direct analog, digital, graphic, and scope output of data. This versatile system obviates costly special-purpose analyzers that are subject to rapid obsolescence.

Monitoring High-Intensity Electron Beams. The heat generated in beam monitors by the high beam intensities of the linear accelerator poses a serious problem. Cooling these monitors becomes essential, and is usually accomplished by circulating water systems. Beam monitors of various types under development include secondary-emission monitors, Faraday-cage monitors, and non-intercepting induction monitors. The major difficulties in all these are maintaining adequate insulation resistance in water-cooled systems and keeping electrochemical potentials small and constant. At present, a secondary-emission monitor for beams up to 100 microamperes is built; a Faraday cage for beams with up to 100 kilowatts of beam power is nearing completion; and efforts continue to develop the non-intercepting induction monitor into a precise instrument.

Electron Scattering Program. One of the major experimental efforts on the linear accelerator will be an electron scattering program. The large (30-in. radius of curvature) magnetic spectrometer for this program has been constructed and will be delivered to NBS in the near future. The performance of this spectrometer as measured using α-particle sources is extremely good.

Theory of Electron Scattering. When electrons scatter they radiate photons with consequent loss of energy. An understanding of these radiative tails is essential for proper interpretation of these experiments. Calculation of these radiative tails for both elastic and inelastic scattering has been made exactly in Born approximation.

Accelerator Shielding Handbook. On July 1, 1964, NBS Handbook 97, *Shielding for High-Energy Electron Accelerator Installations,* was issued. This handbook extends the recommendations of the National Committee on Radiation Protection and Measurements for protection against the radiations from high-energy, high-power electron accelerators. In part, this handbook is an extension of NBS Handbook 55, *Protection Against Betatron-Synchrotron Radiations Up to 100 Million Electron Volts,* issued in 1954.

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Since the publication of Handbook 55, high-energy accelerators, particularly of the linear type, have come into much wider use in research and industry. Their applications in such areas as food processing and general sterilization have generated radiation control problems not encountered with earlier devices.

Compilation and Evaluation of Data

Photonuclear Interactions. Under the auspices of the National Standard Reference Data System, a continuing project for the compilation and evaluation of data in the field of photonuclear reactions (interactions of photons and electrons with the nucleus) was initiated. Work concentrated on abstracting the significant data in the field published during the last 10 years throughout the world and on building a complete file of reprints or copies of the relevant papers. The search of the literature published prior to 1964 is essentially complete.

Electromagnetic Interactions. Improved tables were prepared pertaining to the stopping power and range of electrons at energies between 10 keV and 1,000 MeV. The tabulated information includes the mean energy loss by collision with atomic electrons, the mean bremsstrahlung loss, the mean range, and the conversion of electron kinetic energy into bremsstrahlung energy. Data are also given on critical energies (at which the collision loss equals the bremsstrahlung loss) and on electron positron differences in regard to energy loss and range.

Two-variable proton stopping power and range tables were prepared as functions of the particle energy and of the mean excitation energy of the medium. These tables can be applied to any medium, as characterized by its mean excitation energy, including protons: and, by simple scaling, also to other heavy charged particles.

A tabulation was made of the Vavilov distribution which describes energy loss straggling of fast charged particles. The distribution is a generalization of the well-known Landau distribution, and applies to protons and mesons of moderate velocity traversing extremely thin targets, or to extremely fast particles incident on targets of moderate thickness.

Electromagnetic Cross-Section Theory. The Bethe-Heitler cross section with arbitrary form factor was integrated over all photon angles, without any approximation, for the case of elastic electron scattering. The result was used to calculate the radiative tail due to the emission of real, hard photons. This work was then extended to the case of inelastic electron scattering in which the electron loses energy not only by radiation but also by exciting the nucleus.

Methods for the measurement of the polarization of electrons, positrons, and circularly polarized photons were investigated, with special emphasis on polarization-momentum correlation methods. The various physical processes taken into consideration include Mott, Møller, Bhabha, and Compton scattering, two-quantum annihilation, single quantum positron annihilation, pair production, and bremsstrahlung.

More accurate predictions for the value of the attenuation coefficient for high-energy gamma rays were obtained by calculating the differential and integral cross sections for pair production with the emission of a photon. The total cross section for double Compton scattering was obtained also.

In an investigation of elastic electron scattering by atoms, screening by atomic electrons was shown to affect the cross section at both very small and very large angles. For electron energies above approximately 200 keV, it has been possible to write the cross section as the product of two rather simple factors, one depending only on the screening effect and the other, only on the spin and relativistic effects. The cross section thus obtained is in good agreement with results of previous exact numerical calculations which were vastly more laborious.

Radiation Transport Theory

Charged Particles. Approximate methods were developed for calculating differential and integral distributions of projected range, median ranges, and curves of ionization versus depth (Bragg curves) for protons traversing thick absorbers. The analysis was used to extract the value of the mean exictation energy of the medium from measured Bragg curves.

The penetration and diffusion of electrons were studied by Monte Carlo methods. Direct simulation of the physical scattering processes by random sampling would be prohibitively expensive because of the enormous number of collisions. Instead, the diffusion process is imitated by letting the electrons carry out a random walk, each step of which takes into account the effects of many successive collisions. The calculational scheme is currently being extended to include fluctuations of bremsstrahlung losses and the production of secondary knock-on electrons. The Monte Carlo techniques were applied to the reflection and transmission of electrons by foils, energy dissipation in unbounded and bounded media, and the determination of the slowing-down spectrum.

Electron transmission problems have recently gained increased practical significance in connection with the shielding of spacecraft against Van Allen belt electrons. Detailed tabulations were made of the energy spectra and angular distributions of electrons traversing sapphire foils used as protection for solar cells.

The electron Monte Carlo programs were combined with conventional gamma-ray Monte Carlo programs in a study of bremsstrahlung production in thick targets. Attention focused on the energy region up to 10 MeV. The output of these calculations includes the detailed angular distribution and angular spectrum of photons emerging in the forward and backward directions from slabs of different thicknesses.

Gamma Rays. The output of large cobalt 60 gamma-ray sources (spectral distribution, exposure) was studied by the Monte Carlo method, taking into account scattering and absorption of radiation within the source, the source heading, and the collimator. These results were needed to establish the relation between the source strength in curies and the exposure dose in roentgens for a given source-collimator configuration. They are also used in estimating the difference of actual source spectrum (addition of soft components) compared with the nominal 1.33 and 1.17 MeV spectral lines as functions of the shape of the source, size of the irradiated field, and source-detector distance.

The problem of predicting dose rate and estimating the effectiveness of shielding from radiations resulting from nuclear explosions was the subject of an extensive literature review. Various existing calculations and supporting experiments were summarized, and a set of approximately 500 references was catalogued as to source geometry and energy, absorber material and configuration, type of data presented, and the method of calculation or experimental technique.

An engineering method was developed for calculating protection against fallout radiation provided by various types of protective structures. This work forms the basis of the procedures used by the Office of Civil Defense in the National Shelter Survey and in current shelter engineering research.

A new Monte Carlo method was developed for calculating the reflection and transmission of gamma rays by slabs. This method is the first to allow accurate and convenient determination of the spectrum and intensity of the emergent radiation for specific directions of incidence and emergence. Data generated by this program were used to determine the amount of backscatter when a point-isotropic source and a point detector are placed in the vicinity of an air-concrete interface, and also to calculate the shielding of radiation from a point-isotropic source by a shadow shield.

Neutrons. Thermal neutron flux was studied near the boundary of a semi-infinite non-absorbing gas which scatters neutrons isotropically. Results indicate that the properties of the flux at the surface of a semi-infinite medium, integrated over all spectral energies, are insensitive to various of the scattering properties of the medium.

Monte Carlo data for neutron backscattering from concrete, aluminum, iron, and water were analyzed and compared with the results of Chandrasekhar's theory of radiative transfer for the case of an isotropic single scattering law. The agreement is surprisingly good for non-hydrogenous materials, but not for water. Mathematical expressions derived are suitable for a convenient representation of the energy spectrum and angular distribution of the backscattered flux.

These distributions were used in conjunction with an appropriate transport equation to describe the penetration of slow as well as fast neutrons through long, straight cylindrical ducts. The equation was solved numerically for thermal neutrons in concrete with an assumed isotropic source at the duct entrance.

2.1.11. RADIO STANDARDS LABORATORY

The NBS Radio Standards Laboratory at Boulder, Colo., is responsible for providing the basis of the system of electromagnetic measurement in the United States and for coordinating this system with those of other countries. To do this the Laboratory conducts basic and applied research in the field of radio science. This research leads to the development and evaluation of national standards for all important radio quantities, which are then maintained as the national basis of electromagnetic measurements. At the same time extensive contact is maintained with other laboratories and with industry to provide continual interchange on the developing state of the art.

In addition to the national standards, the output of the Laboratory includes calibration and broadcast services which furnish standards of radio measurement to hundreds of industrial and government laboratories; accurate design data for radio materials; new measuring devices which the instrument industry can produce; new theories which radio scientists can exploit; and publications, consultation, and instruction to assist other laboratories in the solution of problems in this field. The unique competence of the Laboratory in radio and microwave measurement is also used to explore selected atomic and bulk properties of matter and to improve the determination of fundamental physical constants.

Substantial interest has been expressed by other countries in NBS achievements in radio science. NBS microwave measuring equipment, for example, is now being duplicated by some European countries and interest in this has been expressed by others. Also, as part of an exchange program between the United States and Russia, three Russian metrologists visited the Radio Standards Laboratory during January 1964.

The Laboratory is continuing its efforts to assess accurately the national needs for radio standards and then to establish the activities needed to satisfy these needs. Close contact is being maintained with industry, for example, by a series of seminars in which selected speakers describe their measurment needs or new developments in their field. Five such seminars were held during the past year, the presentations of which are receiving a detailed analysis.

Contact with both research and industry is stimulated by the biennial Conference on Precision Electromagnetic Measurements. The fourth conference in this series, held at the Laboratory during June 1964, was attended by more than 600 participants. Although the Conference is national in sponsorship, it receives international participation and is now firmly established as a significant forum for the interchange of ideas. This fact was recognized recently in a formal charter signed by the three sponsoring organizations: the National Bureau of Standards, the Institute of Electrical and Electronics Engineers, and the U.S. National Committee of the International Scienific Radio Union.

As the needs of industry are discovered through seminars, conferences, and personal contacts, this information is incorporated into the Laboratory's long-range planning. The Laboratory capabilities are compared annually with the needs of industry to set the goals for the program for the next 5 years.

The Laboratory continued to develop an educational program for industrial and research personnel by offering a three-week course in electromagnetic measurements and standards during July and August of 1963. It was attended by 153 scientists from the United States and 5 foreign countries, representing industrial organizations, universities, and government laboratories. Since the course was well received, present plans are to offer it again during the summer of 1965.

Theoretical Physics. Theoretical work completed during the past year may provide the first successful calculation of properties of a plasma model that is more realistic than the familiar electron-gas model. In this study, a new theory of the quantum statistics of multicomponent systems was applied in calculating the thermodynamic properties of a fully ionized gas in thermal equilibrium. The computations carry the expansions to a higher order than done before, and obtain corrected lower-order terms.

Recent developments in antenna theory emphasize the use of vectorial angular spectra and the "scattering matrix" description of radiating and receiving systems. This approach seems well adapted to the formulation and analysis of problems involving near-zone or Fresnel-zone interaction of antennas and led to results permitting electromagnetic field measurements with arbitrary probes.

2.1.12. RADIO STANDARDS PHYSICS

The Bureau's program in radio standards physics emphasizes fundamental research on the interaction of electromagnetic fields with matter. It is particularly concerned with research having application to radio standards, frequency standards, time scales, atomic and aggregate properties of matter, and constants of physics. It also establishes standards of measurement in the areas of frequency, time, and radio materials, and disseminates these standards to the general public. The program for electromagnetic standards is firmly linked to the requirements of both industrial and government laboratories. The staff provides a readily available consulting service to industry, government agencies, and individuals.

Frequency and Time Dissemination. Dr. Allen V. Astin, Director of the Bureau, dedicated the Bureau's two new standard frequency broadcast stations, WWVL (20 kilohertz, kHz) and WWVB (60 kHz), in August 1963. They are located near Fort Collins, Colo., about 50 miles northeast of Boulder. The standards at the Boulder Laboratories directly control the carrier frequency of each of these stations by a 100-mile round-trip servo loop between Boulder and the transmitters. This unique feature makes these transmissions the most accurate and stable frequency transmissions in the world. The servo system removes phase perturbations caused by the controlling oscillator, the antenna system, and the transmitters.

The propagation characteristics of low radio frequencies enable station WWVB to provide excellent stability and coverage over the continental United States. WWVL, still in the experimental stage, provides good stability and coverage over much of the globe. The importance of these transmissions is accented by the partial support provided by the National Aeronautics and Space Administration for the development and construction of WWVL.

Additions were also made to the services offered by the shortwave standards stations WWV (near Washington, D.C.) and WWVH (Hawaii). A new announcing machine at WWV improved both the reliability and precision of the voice annoucements and made possible propagation forecasts every 5 minutes instead of only every 30 minutes. Another announcing machine was installed at WWVH to enable this station to give voice announcements for the first time.

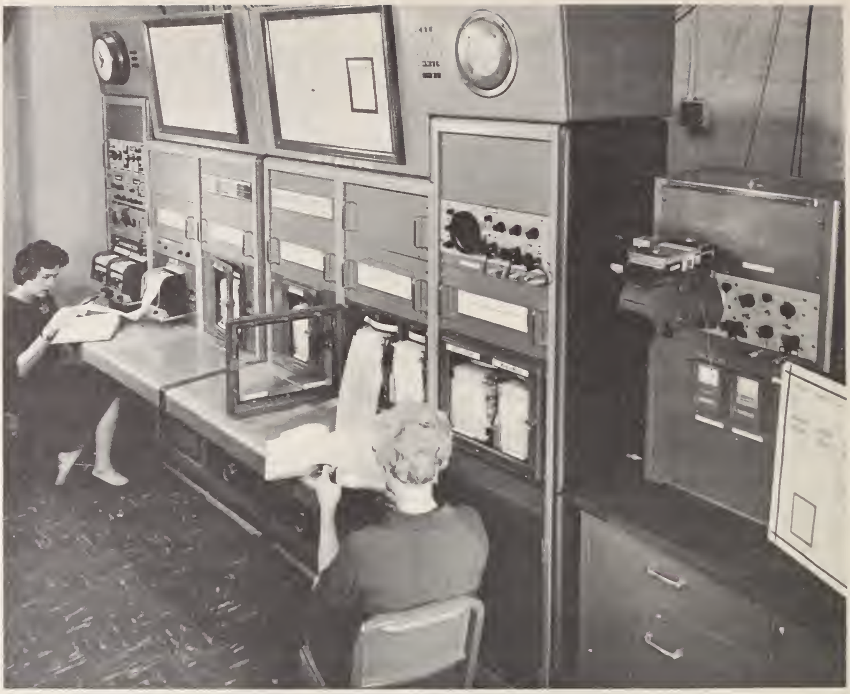
Atomic Frequency Standard Research. The new cesium-beam frequency standard, NBS III, was evaluated and its accuracy found to be $\pm 5 \times 10^{-12}$. The precision was found to be $\pm 7 \times 10^{-13}$ typically, attaining a value of $\pm 1.4 \times 10^{-13}$ in the best cases.

This frequency standard and two smaller cesium-beam devices provide the basis for the NBS atomic time scale (NBS–A), and for a second time scale maintained at a determined offset from NBS–A (presently 1.5×10^{-8} sec). The second time scale is denoted NBS–UA, since it is essentially an approximation to Universal Time derived from an atomic device. A uniform time- and frequency-generating device maintaining the NBS–UA time scale is now used to control the phase of transmitters of radio stations WWVL, WWVB, and WWV.

Both atomic time scales are derived from the same system and use several high-precision quartz crystal oscillators, as well as a rubidium gas cell to interpolate between calibrations made with the U.S. Frequency Standard. The reliability of this clock system was improved during the past year by increased redundancy, and the precision improved from $\pm 1 \times 10^{-11}$ to $\pm 3 \times 10^{-12}$. The automatic data-handling capability of the frequency and time standards was doubled and it is therefore now possible to compare two secondary oscillators with the U.S. Frequency Standard simultaneously.

A hydrogen maser is being developed to study the effectiveness of such a device as a frequency standard. Basic construction was completed during the past year and stimulated emission observed. Present work is aimed at refining components to make possible self-sustained oscillations.

International Comparison of Atomic Frequency Standards. The international comparison of atomic frequency standards, begun in 1961, was continued using the very-low-frequency signals of GBR (16 kHz) at Rugby, England, and NBA (18 kHz) at Balboa, Canal Zone. The atomic standards in England, France, Switzerland, and Canada agreed with those at NBS to within 3 parts in 10^{10} in the worst case and to within 1 part in 10^{10} for the better ones. Hewlett Packard comparison of the Swiss and NBS standards by means of portable commercial cesium beam units shows



Equipment used for the international comparison of atomic frequency standards using the VLF signals of Radio Stations GBR (England) and NBA (Canal Zone). Such studies showed that atomic "clocks" in England, France, Switzerland, and Canada agreed with those at NBS Boulder to within 3 parts in 10^{10}. **(See page 109)**

agreement within 1 part in 10^{11}. It is planned to extend this work to include Japan, Australia, Sweden, and India during the coming year.

Quantum Electronics. The Stark effect—the splitting of spectral lines by the application of an electric field to a material absorbing or emitting radiation—offers the possibility of measuring high voltages with precision. A completed apparatus based on this principle utilizes a Fabry-Perot absorption cell and uses a rotational transition of methyl cyanide at 37 GHz. A preliminary evaluation indicates that the precision obtained is of the order of a few parts in 10^6 but the accuracy is not likely to be better than a few parts in 10^4. The present equipment operates with inputs under 5,000 volts, but if the method proves to be practical it will be useful primarily for measuring voltage ratios at about 100 kilovolts. Evaluation of the device is continuing, with this application in mind. This project is supported partially by ARPA.

Lasers are presently being used at NBS as a source of intense, coherent, monochromatic optical radiation to investigate nonlinear optical properties of materials. This is directed toward a better understanding of the characteristics of lasers and, eventually, the development of national measurement standards.

An ordinary ruby laser was used to observe stimulated Raman radiation in benzene. A *Q-switched,* Raman-scattering laser was used to observe the double quantum absorption in anthracene crystals. It was also used to observe coherent Raman radiation from benzene in an optical resonator, which was external to the optical resonator of the ruby laser. The axes of the two resonators were at a small angle to each other to permit them to resonate independently of each other.

A symmetric-top molecule, CH_3CN, was studied by three-level maser spectroscopy at 37 GHz. The molecule was subjected to radio-frequency energy introduced into a Fabry-Perot type millimeter-wave resonator on a multiple-wire grid placed between the reflectors. The results agreed approximately with the theory of multiple quantum transitions.

Other research in progress in the area of quantum electronics includes measuring the velocity of gamma rays using the Mössbauer effect and measuring the fine structure separation in singly ionized helium. The latter will help in obtaining a better value for the fine structure constant.

Radio and Microwave Materials. Research on electromagnetic materials is designed to improve understanding of the magnetic (primarily ferrimagnetic), dielectric, and conductive behavior of materials at radio and microwave frequencies in terms of the atomic constitution and structure of matter. This research is intended also to improve and develop standards and electromagnetic measuring techniques.

Magnetics. A study of the accuracy of ferrimagnetic resonance line width and gyromagnetic ratio measurements on ferrites and garnets at 1106 MHz revealed several anomalies and problems connected with disk-shaped samples. In other experimentation an intermediate frequency attenuation-substitution method was found to compare favorably with accurate frequency-measuring techniques in plotting ferrimagnetic resonance curves.

A knowledge of spin relaxation mechanisms in solids is vital to understanding magnetic resonance phenomena and to planning experiments involving photon and phonon masers. The staff is investigating these mechanisms and studying relaxation times and resonance line shapes with approach to equilibrium, and the dependence of the mechanisms on external fields, frequency, and temperature. A paper completed during the year provides exact equations for use in analyzing the approach to equilibrium in many-body systems. The theory of longitudinal spin-spin relaxation is now being studied from both a thermodynamic and microscopic point of view.

Paramagnetic and antiferromagnetic crystals are being studied by magnetic resonance techniques to improve our knowledge of the solid state and its interaction with electromagnetic radiation, as well as to collect basic information to apply these materials in the microwave and submicrowave region. A useful ferric-ion electron paramagnetic resonance (EPR) spectrum was obtained in these studies from a brown specimen of iron-doped quartz. It was thoroughly studied at *K*-band frequencies and room temperature, and the data were analyzed. Equipment was built for experiments in the field of electron-nuclear double resonance and on nuclear-spin transitions induced in antiferromagnetic $KMnF_3$ by ultrasonic modulation of the hyperfine interaction.

Research in the optical region of the electromagnetic spectrum included studies of the fluorescence of manganese sensitized by cerium in single crystals of calcium fluoride. The cerium absorbs ultraviolet photons and transfers this energy to neighboring manganese ions; the managnese then fluoresces in the visible region. This sensitization is believed to be due to an electron spin exchange process. With a sufficiently high ultraviolet intensity, the energy transfer to the manganese approaches saturation while the quantum efficiency for cerium fluorescence increases. A simple physical model was developed to explain this effect. From observations of the fluorescence as a function of ultraviolet intensity one can estimate the number of lattice sites surrounding the cerium which can be sensitized.

Materials Synthesis. Sometimes study of a fundamental process requires that materials of controlled composition be obtained. This is particularly important in experimentation on specimens of radio and microwave material. Fairly large (3 to 4 mm) crystals of anyhdrous sulfates of some transition metals were grown for studies of antiferromagnetic properties at low temperatures. Both pure and doped (with cobalt, chromium, and iron) calcite crystals (1 to 2 mm) were grown for studies in electron paramagnetic resonance.

Dielectrics. Three dielectric materials—fused silica, glass, and alumina—were evaluated in international comparison with Canada and England. The three laboratories agreed within better than 1 percent for the real part of the permittivity, but disagreed more for the imaginary component, in the measurement of which accuracy is much more limited. A second round of measurements is in progress, with the expectation that closer agreement will result.

The international comparisons led to refinements in the standardization of the dielectric constants of the glass and the silica, standardized samples of which are now available for issue. For these the real part of the dielectric constant is specified to ± 0.4 percent and the loss tangent to ± 10 percent or ± 0.0001, whichever is larger.

The results of a study on the effect of aging on certain dielectric materials are now being used in the design of precision coaxial connectors and terminals. Also, a system was modified to permit the precision measurement of dielectric properties at several frequencies from 80 to 573 °K. Measurements on polycrystalline silver iodide by means of this system revealed a correlation between the complex dielectric constant and the thermal expansion coefficient, which becomes positive in the temperature interval 80 to 110 °K.

Both theoretical and experimental work on nonlinear dielectrics is being started to develop better techniques for measuring the complex dielectric constant of materials at millimeter and submillimeter wavelengths.

Microwave Physics. Use of the higher radio waves—above about 100 GHz—is hampered by a lack of instruments to generate or detect these frequencies. The staff developed a microwave spectrometer for use at such frequencies and now is using it to study the properties of molecular oxygen, transitions among the energy levels of which generate a spectrum above 60 GHz. The 119-GHz line could not be observed with the straight-line absorption cell, but a spherical Fabry-Perot resonator now being tested is expected to provide the necessary sensitivity.

Radiometry. Correlation radiometers are widely used to measure radio noise despite the sizable discrepancies between the performance of radiometer circuits and the predictions of the usual idealized theory. During the past year the theory of the correlation radiometer has been further extended to include the effects of amplifier gain fluctuations and of amplifiers with different characteristics in the two channels of the instrument. Analysis allows referring the sensitivity of a radiometer in which two noise sources are being compared to a second radiometer in which the output of the noise source is compared to a continuous wave signal.

Microwave-Stimulated Transitions. A study of the interaction of microwave energy with excited free molecules resulted in the optical detection of microwave transitions in the excited gaseous CN molecule and observation of all 13 of the predicted absorption lines. A complete energy-level diagram of this rotational level was prepared by observation of the microwave transitions. A byproduct of this research was the development of a compact and efficient microwave discharge cavity for use at 2450 MHz in the dissociation of N_2.

Interferometric Measurements. The past year was spent perfecting techniques for measurement with the Michelson interferometer and searching for the systematic errors in the system. Measurement of the velocity of light at millimeter wavelengths with this interferometer reached the final stage.

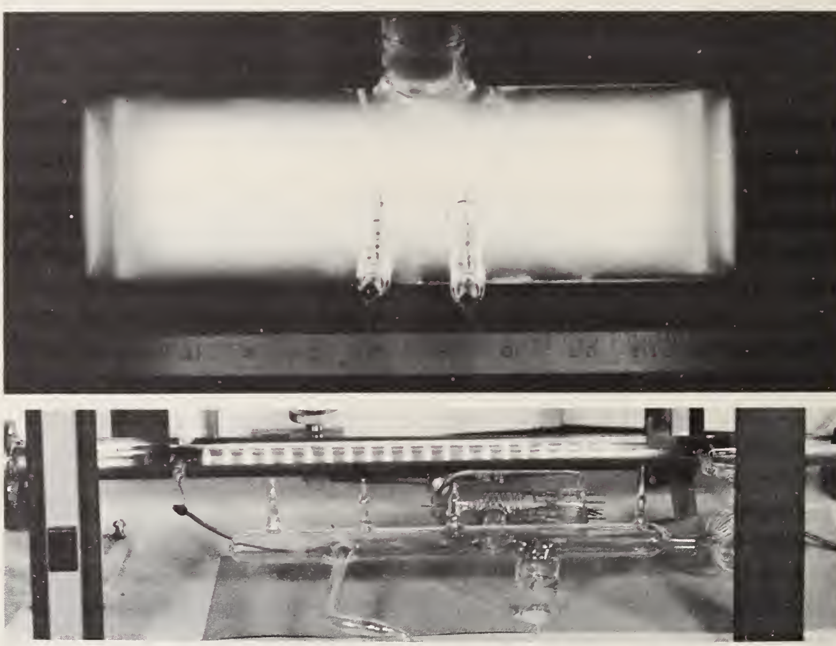
A significant error was found to be created by reflections originating in the throat of the interferometer horn, near where the horn taper approaches waveguide dimensions. Errors from this source were reduced by the design of a new waveguide-to-horn transition which was electroformed in a smooth curve, thus avoiding a discontinuity. Multiple reflections were further reduced by the use of matched phenolic plastic plugs of various thicknesses in the large end of the transition. It is now felt that averaging techniques can eliminate any remaining errors due to multiple reflections. With these improvements it is possible to make measurements consistently with a precision of about $\pm 3 \times 10^{-7}$, or better. This work has recently been supported partially by ARPA.

Brush-Cathode Plasma. A major reason for characteristics of plasmas not being clearly understood is the general lack of fast, accurate, and convenient diagnostic techniques. The development of such techniques is thwarted, in turn, by the enormous complexity of most plasmas. The recent NBS development of a new form of plasma—the brush-cathode plasma—which is both stable and uniform is a major achievement in this field. The negative glow associated with the brush cathode is particularly interesting because it constitutes a well-behaved medium for a series of investga-tions in the field of plasma physics. The plasma in its normal condition is beam-generated and recombination-dominated.

Investigations of the brush-cathode discharge show that its negative glow, and probably that of all other discharges, is an electron-beam-maintained plasma. The beam energy is approximately equal to the cathode fall (200 to 5,000 volts at 1 torr) and the beam current is approximately equal to the discharge current. The high fields and potentials in the cathode region are measured with Langmuir probes and by observations of the linear Stark shift and splitting in the transition. The fields in front of the cathode are found to be in the range 10^3 to 10^4 volts/cm by these means, to an agreement within 10 percent. Among other experiments now being conducted on the brush discharge are an investigation of possible laser action and a study of the scattering of light by the electrons in the ionized gas.

Plasma Measurements. As a result of the development of the brush-cathode plasma, the diagnostic program now includes plasma investigations using Langmuir probes, resonant probes, microwave interaction; and spectroscopic measurements. This program will also establish the reliability, compatibility, and useful ranges of these diagnostic tools in measuring electron densities, electron temperatures, and collision frequencies.

Spectroscopic measurements are particularly important, under certain conditions making it possible to observe emission in the helium series $2s^3S - np^3P$



Almost all laboratory produced plasmas are non-uniform and exhibit structures caused by non-linear flow mechanisms (above). A recent NBS development of a new form of plasma—the brush-cathode plasma (below), which is both stable and uniform—presents a major achievement in this field.

(See page 113)

up to the quantum number $n = 30$. This series is used for measuring electron density and the electron temperature. The electron temperature is in the range 0.05 to 0.10 eV, spectroscopic measurements of which are in excellent agreement with Langmuir probe measurements. The electron density is in the range 10^{11} to 10^{14} cm^{-3}, similarly well-confirmed by measurements with a microwave interferometer. These and other precision measurements can only be made in a well-behaved medium, such as the brush-cathode plasma.

The series of instruments developed to study the brush-cathode plasma includes: a microwave noise radiometer with a sensitivity of better than 10^{-15} watts for electron temperatures and rf emission measurements; a portable interferometer operating at 8 mm Hg and used to measure electron density versus plasma current; a ring-shaped probe for use with a Faraday cage to eliminate the effects of secondary emission and metastable atoms in the plasma; and, presently under investigation, two new methods of determining beam properties of a plasma.

Bounded Plasmas. Electromagnetic waves in bounded laboratory plasmas were examined to find the effect of boundaries on waves traveling longitudinally in a magnetoplasma, and to determine the resulting quantitative changes in the wave, compared with an infinite plane wave. A 5-inch brush electrode discharge will be used in experiments to test some theories.

2.1.13. RADIO STANDARDS ENGINEERING

The Bureau's program in radio standards engineering includes basic research on physical principles and fundamental engineering techniques having applications in the field of precision electromagnetic measurements. This research leads to the establishment, maintenance, continued improvement, and international coordination of a comprehensive set of national standards and precision measurement techniques for fundamental electromagnetic quantities in radio circuits. Dissemination is accomplished in large part through calibration services, and information is distributed widely through publication, consultation, conference papers, invited talks, committee work with technical societies, individual visits to other laboratories and the NBS-Air Force Working Group visits to Air Force contractors.

Low-Frequency Calibration. A new voltage calibration method, which uses inductive voltage dividers to establish audio frequency voltage ratios, is now the basis for calibrations on inductive voltage dividers at 400 and 1000 Hz. Multisection dividers are used, for which relative errors are calculated at each tap and absolute measurements made at certain non-zero-error taps. This information is combined to obtain accurate values of in-phase voltage ratio and phase angle at all taps.

A service was begun for the calibration of multi-megohm resistors to 10^{10} ohms with an uncertainty of ± 0.01 percent and to 10^{14} ohms with an uncertainty of ± 1 percent. This system depends on a Wheatstone bridge using high-quality wire-wound resistors in a wye-delta ratio circuit. All

This new calibration console for loop and dipole antennas at 30Hz to 1GHz provides a significant improvement in NBS calibration services.

(See page 119)

components are incorporated in a measurement console.

Most of the research and development was completed for a new temperature-stabilized oil bath for saturated cells. Electronic circuits will control oil temperature to within 0.001 °C of any temperature between 23 and 40 °C. The bath will be set to operate at a temperature of 28 °C.

Agreement to within a few parts in 10 million was achieved between the NBS voltage standards at the Boulder and Washington laboratories in measuring the average electromotive force (emf) of a Boulder traveling group of saturated standard cells. It is expected that even better measurements of emf will be obtained when the installation of a new standard cell comparator in the Boulder Electronic Calibration Center is completed.

Improved voltage standards for a-c–d-c transfer measurements were built, using plug-in wire-wound resistors for changing from one voltage range to another. Corrections for these prototype standards, at frequencies between 20 Hz and 50 kHz, are less than ±0.001 percent. New current standards for a-c–d-c transfer are now being developed.

An experimental inductance bridge employing inductively coupled ratio arms was assembled to measure equivalent parallel inductance in terms of capacitance and frequency. The measurements compare very favorably with those by a precision Maxwell-Wein bridge at the 100 millihenry level. Further development is planned.

A study of the effects of oil circulation on the temperature of oil-cooled shunts was completed. As a result of this study, modifications were made in the shunt oil bath that will provide better accuracies in reported values. A method for determining accurately the heating effects in master volt boxes was developed which will improve ratio accuracies.

High-Frequency Standards. The Bureau completed a prototype noise power comparator which compares power at 3 MHz from noise generators having effective noise temperatures between 75 and 30,000 °K with an uncertainty of less than 0.5 percent. This prototype will serve as the pattern for comparators for calibrating noise factor instruments over a wide range of frequencies.

Electromagnetic Measurements. A special bolometer and resistance element combination was developed to eliminate dual bolometer error in radio frequency (rf) voltage measurement and has promise of yielding accuracies within 0.1 percent up to 500 MHz.

Electric-field standards were developed for the frequency range of 300 to 1,000 MHz. NBS now has electric-field standards covering the range of 30 to 1,000 MHz with an uncertainty of about 0.8 decibel (dB).

A thermal noise generator, cooled by liquid nitrogen, was constructed for use at 30 MHz. Its electrical and thermal characteristics are being evaluated in preparation for its use as a working standard of noise power. Other noise generators for operation at various temperatures are being constructed with adjustable output impedances which essentially eliminate mismatch errors.

A special correlation detector was developed for use in 30–MHz attenuation-measuring systems, permitting simultaneous phase and amplitude nulling in the measurement of complex insertion ratios. This precise detector achieves a sensitivity of 36 picovolts with a 30-second integration time, which is only 17 percent greater than the theoretical limit. Performance tests indicate the detector will aid in the development of insertion-ratio measuring systems by providing greatly increased range, accuracy, and convenience.

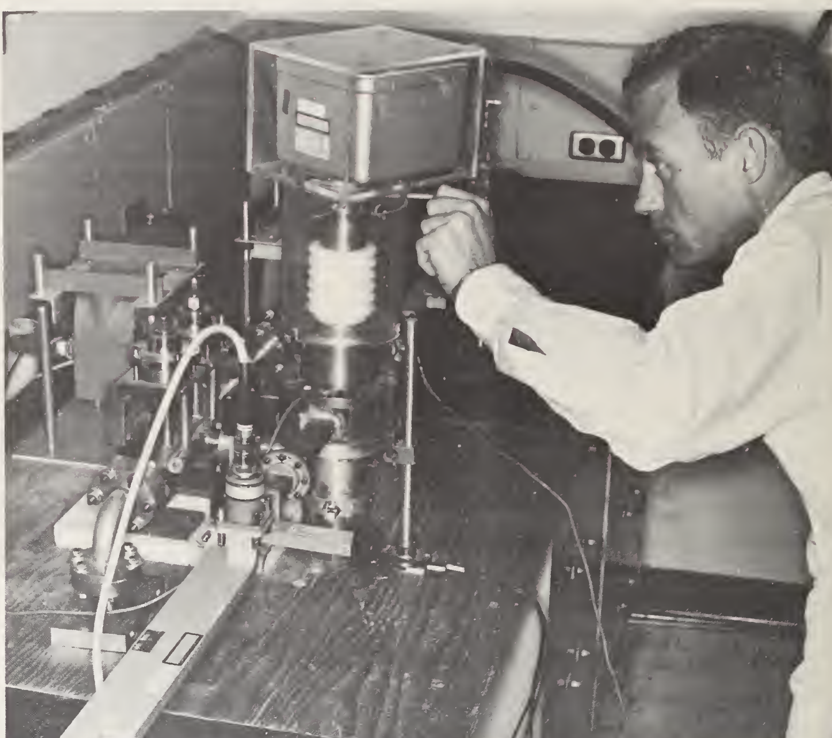
A new calorimetric reference standard for rf power measurement in the frequency range 30 kHz to 1,000 MHz was completed and evaluated. The accuracy of the standard is within 0.25 percent and the power range is 5 to 100 watts. This equipment augments other reference standards, which extend downward in power level to 10 milliwatts.

International comparison of rf power standards is proceeding on schedule; comparisons with the United Kingdom were completed in 1962 and with Japan in 1963. Comparison measurements with Canadian transfer standards are in progress.

Two systems have been developed for the standardization and measurement of the peak voltage amplitude of short-duration, fast-rise, d-c, or unidirectional pulses. The accuracy of both systems is within 0.2 percent in the range of 1 to 100 volts peak. These systems are expected to form the basis of reference standards up to several thousand volts.

A dual twin-T bridge circuit was developed to make resistance measurements directly in terms of capacitance and frequency up to a few hundred megahertz. A model of this bridge, which operates at 1.5 MHz, is proving useful not only in the determination of resistance and reflection coefficient standards, but also of the rf–d-c difference of thermoelements used in standards and for precise measurements of Q and loss. Construction of another model for use at 150 MHz was started. Evaluation of errors shows that the bridge should be capable of measurements to a few parts per million, but present measurements are limited by mechanical problems in capacitance standards and instabilities in resistance to several hundred parts per million at 1.5 MHz.

A high-frequency ratio transformer bridge now under development demonstrated capabilities of a few parts per million at 1 MHz. It is being built for use with new high-frequency inductance standards and to increase the accuracy of high-frequency capacitance measurements by three-terminal techniques.



X-band electron-beam power meter developed for application at very high powers. It is being used in a radar measurements standardization program for DOD. **(See page 120)**

An all-coaxial reflectometer was put into operation in the frequency range of 0.1 to 1 GHz; the connectors, tuners, couplers, loads, and center-conductor supports used in it are sufficiently precise to reduce measurement uncertainty to 0.1 percent. This, with the time domain reflectometer and associated standards, is proving useful not only in the development of reflection coefficient standards, but also in the design of high-precision coaxial components, particularly connectors.

An important task now well under way is the construction of an electrodynamic ammeter for measurement of current in terms of mechanical properties and time. Operating at frequencies from about 0.1 to 1 GHz and to an estimated accuracy of 0.1 percent, this instrument should be of considerable value. It will be used not only as an accurate absolute standard of rf current, but also as a basis for establishing rf–d-c corrections for thermoelement standards used in determining other quantities such as voltage, power, and field strength, supplementing the impedance correction system now in use.

High-Frequency Calibration. The Bureau made significant progress in extending calibration services to greater powers and higher frequencies to meet the perennial need for growth in calibration capabilities. The high-frequency field-strength calibration services for horizontally polarized dipole antennas were expanded from 300 to 1,000 MHz; dipole antennas can now be calibrated at any frequency from 30 to 1,000 MHz. The present calibration uncertainty for this new service is approximately 12 percent—about twice as good as the best previous measurements. The uncertainty in calibration at 150 to 300 MHz was slightly improved, and recent progress in evaluating measurement errors may result in further improvements in calibration uncertainty at all frequencies from 30 to 1,000 MHz. A recently completed calibration console for loop and dipole antennas at 30 Hz to 1,000 MHz significantly reduces the time required to calibrate these antennas, thereby improving efficiency and reducing calibration costs.

Improved standards for the calibration of Q-meters over the frequency range of 50 kHz to 45 MHz were established by a statistical procedure for adjusting the values of the NBS standards. These procedures also yielded improved tolerance limits for future calibrations. Significant progress was also made toward the development of a coaxial reflectometer system for the measurement of VSWR at frequencies of 1.0, 2.0, 3.0, and 4.0 GHz. Slotted-line calibration capabilities were improved by the addition of two new high-precision lines which extend calibration capabilities to the region of 8 GHz.

Plans for constructing rf bridges for calibration purposes were changed slightly; bridges covering a range of frequencies are now deemed more practical than bridges for fixed frequencies. The former are being constructed, and previously constructed bridges modified for broader frequency application. Although this entails a sacrifice in convenience, fewer bridges will be required, thus saving research and development expense.

A continuous-wave power calibration service is now offered at power levels from 1 milliwatt to 100 watts at 500 MHz for coaxial rf calorimeters having Type N connectors. Calibration uncertainty is ±1 to 2 percent, depending

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upon the stability and standing-wave ratio of the calorimeter being calibrated.

The attenuation calibration capability was substantially increased by raising the upper frequency limit from 5.6 to 12 GHz. Improvements in a reflectometer system increased measurement accuracy from 0.1 to 0.01 dB in 10 dB in the frequency range of 1 to 12 GHz. Phase shift calibration in the 0.2 to 12 GHz range was started and completion scheduled for early 1965. A program for coaxial attenuation measurements from 12 to 18 GHz was started and completion is scheduled for the next fiscal year. A project to increase 30 MHz calibration accuracy from 0.005 to 0.001 dB in 10 dB was begun, with completion scheduled for November 1964.

A calibration console put into service for rf voltage measurements at 500 MHz covers a range from 0.2 to 7 volts at an accuracy of 5 percent. The working standards used in this console consist of a set of frequency-compensated thermal voltage converters, which are calibrated in terms of the national reference standard.

Microwave Standards. The international significance of NBS achievements in microwave standards is demonstrated by such instruments as the NBS low-power calorimeter, which continues to attract visitors from around the world. During the past 18 months three European countries have expressed a desire to duplicate NBS microwave power-measuring equipment.

A water bath now being developed for the calorimeter will further narrow the range of uncertainty of bolometer mount efficiencies. Thermal variations and gradients in the new bath remain under 0.00005 °C for room temperature changes of ± 1 °C over a period of hours, and still further improvement is expected.

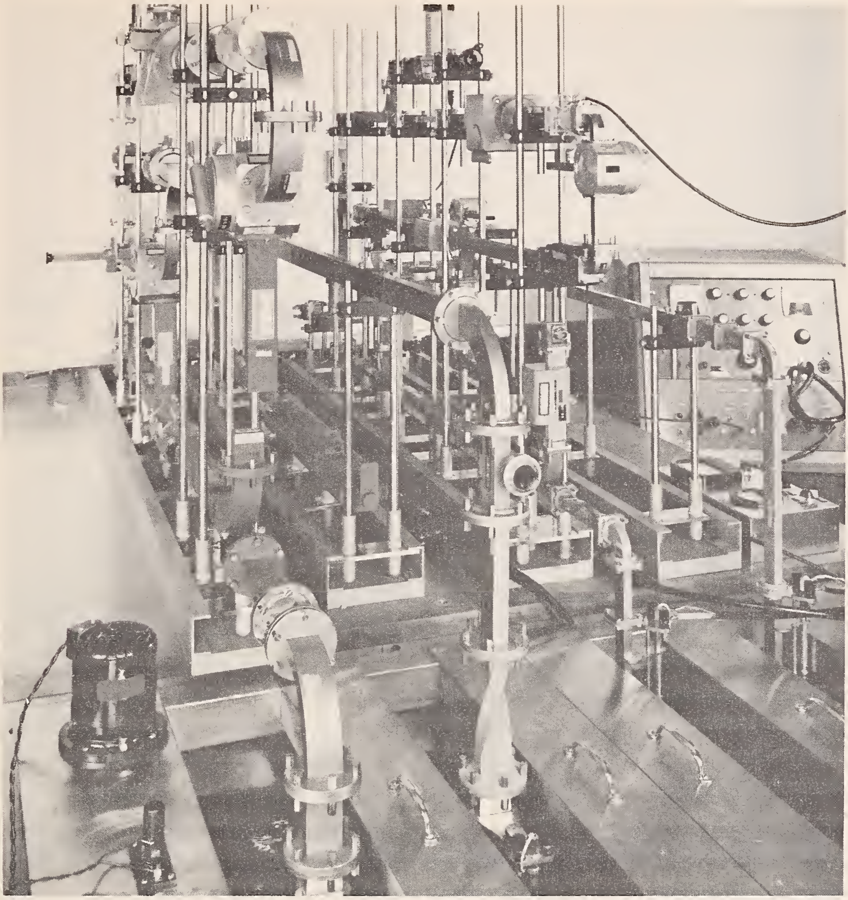
A newly developed technique is used to transfer calibrations between power meters of different input waveguide types or sizes. This technique makes it possible, for example, to calibrate a coaxial bolometer mount in terms of a rectangular waveguide standard.

Work on microwave high-power standards was accelerated during the past year, supported by ARPA. This led to stepped-up development of an electron-beam power meter, a frequency- and power-stabilized 200-watt microwave source, and a high-power stirred-water calorimeter. Similar ARPA support in the microwave noise standards program is permitting initial development of cryogenic noise standards and measurement techniques.

The evaluation of precision coaxial connectors in cooperation with the Institute of Electrical and Electronics Engineers continued with emphasis on procedures for investigating the proposed 7-millimeter connector over the frequency range of 2 to 18 GHz.

Waveguide loss measurements are being made to narrow the limits of uncertainty in the value of the X-band national standard short circuit, using both the X-band reflectometer and the microcalorimeter.

The 70-GHz reflectometer was improved by cophase-locking the signal generator and the local oscillator to the Boulder Laboratories 100-kHz reference frequency and by using improved waveguide components. The instrument is now being used to measure millimeter waveguide attenuation and to evalu-



These systems in WR137 and WR90 waveguides are the first of several calibration systems which use the impedance method to measure the efficiency of a bolometer unit. **(See page 122)**

ate millimeter waveguide connectors. Preliminary data on an electroformed precision WR12 waveguide (60 to 90 GHz) showed the loss to be approximately 1 dB per foot. The measured coefficient of reflection from a UG–387/U connector was 0.006 for a VSWR of 1.012.

Efforts to suppress leakage in reflectometer systems resulted in the development of gaskets of perforated and metallized fluorocarbon, which confined rf leakage to below a detectable amount. The gaskets are also expected to provide adequate pressure seals.

A single measurement system that will measure attenuation to ± 0.005 dB in 10 dB, phase shift to $\pm 0.1°$ in $360°$, and complex impedance to corresponding accuracies is under development. Its capabilities were used in a coaxial waveguide system in the 1- to 2-GHz band. Refinements, including automatic phasing, are being developed to simplify the measurement procedure. Also, during the past year comparison of microwave impedance standards was made with the Swedish Standards Laboratory.

Microwave Calibration. Two European countries are presently duplicating the NBS microwave noise calibration system. NBS is already beginning an international comparison of microwave noise with these countries by making measurements on an interlaboratory standard which will be calibrated later by the other countries. The development of a new tube mount improved interlaboratory and working standards and led to significant improvements in the calibration of microwave noise sources.

A power calibration system developed for WR137 waveguide is the first of several systems using the impedance method for measuring low-level continuous wave (CW) power at frequencies less than 10 GHz. Calibration services for additional waveguide sizes, at frequencies from 2.6 to 10 GHz, will be announced soon. The calibration procedures using this method have been considerably simplified during the developmental work, and further refinements are expected as the work progresses.

Attenuation calibration systems using the modulated subcarrier method of measurement were completed and calibration services are now available for variable waveguide attenuators in WR90 and WR62 waveguide. This method of attenuation measurement, developed by NBS, provides an improvement in measurement accuracy of one order of magnitude or better. Other attenuation calibration systems using this method are being developed for additional waveguide sizes.

A system to measure frequency stability of signal sources was completed, and calibration services were announced for frequencies up to 500 MHz. Additional capabilities now planned will provide similar calibration services extending into the microwave region.

2.2. INSTITUTE FOR MATERIALS RESEARCH

There is great demand and pressure everywhere for a more functional, resourceful, and precise utilization of materials. To give substance to his complex and imaginative designs, the modern technologist draws upon a far more extensive and varied inventory of materials, with a vastly broader range of properties and performance, than was available to his predecessors only a few decades ago. Any one equipment system embodies a host of materials, each of which has its own specific function, and each of which must also work harmoniously with all the others in order to carry out the desired overall function. Also, materials are continually being required to perform, often with high precision, under environmental conditions of a severity never before encountered—conditions of extreme heat or cold, pressure or vacuum, radiation, force and shock, and others.

Since, in one way or another, materials are involved in all end items of our national output, any increase in basic knowledge of materials, any enlargement of our power to control, produce, and design materials for better performance, obviously will benefit productivity and utilization all along the line.

For many years the National Bureau of Standards has been active in the generation, collection, and dissemination of data on the properties of materials. It has developed methods for the preparation, purification, and characterization of research materials in order that meaningful measurements of their properties might be made, it has developed precise methods for making such measurements, and it has developed procedures for promoting uniformity of measurement in technology and industry.

Within the last year, in order to give maximum support to the national materials effort, the Bureau has realined and refocused its programs dealing with the structure and behavior of matter. All materials groups of the Bureau are now concentrated in the recently formed NBS Institute for Materials Research (IMR), permitting a strengthened and more closely coordinated attack on the materials problems that have been traditionally a major NBS responsibility. Specifically, this realinement is planned to give direct support to one or more of the following NBS objectives:

Preparation of Research Materials

Research materials are materials which have been prepared in such a manner as to have special characteristics, i.e., high purity, well-defined structures or composition, specific properties, etc. Such materials are essential for measurements of a meaningful nature. The development of methods for their preparation, purification, and characterization is, therefore, a matter of utmost importance to the scientist and engineer concerned with the use of materials in a wide variety of environments. One of the primary objectives, therefore, of this program is to produce new methodology for the preparation, purification, and characterization of such materials.

The ability to prepare these materials is also essential to a number of NBS missions: (1) they are necessary as backup to the National Standard Reference Data System both to make available material to verify research data entering the system and to provide new critical data; (2) they are the basis of the Standard Reference Materials program; (3) they are essential to NBS programs concerned with obtaining better understanding of the bulk properties of materials in terms of their microscopic structure; and (4) they are necesssary for defining basic physical standards that depend on a stable physical or chemical property of a material.

Standard Reference Materials

The provision of these materials directly supports national science, technology, industry, and commerce. Through this activity of long standing, more than 600 kinds of standard reference materials are prepared, certified, and distributed. These standard materials are certified either for chemical composition or for a particular stable physical or chemical property. To support this program a new Office of Standard Reference Materials has been established. The staff of this Office will conduct studies of the needs for these materials in all areas of our technology and will be particularly concerned with determining where well-characterized materials should be used to calibrate a measurement system.

The availability of standard reference materials is of tremendous importance to our economy in several ways. These reference materials allow a high degree of quality control throughout industry. Secondly, the use of these materials provides a laboratory or industry with a self-calibration ability which directly benefits both research and development activities as well as production and control activities, insuring better research and engineering data and design. Finally, the most diffuse and possibly the greatest benefit from the use of standard reference materials is the general promotion of uniformity of measurement throughout the Nation.

Measurement of Bulk Properties of Materials

New measurement techniques for determining the properties and performance of materials are constantly required as our industrial technology demands that materials be used in new environments. The objectives of the IMR programs in this area are (1) to develop methods of measurement that have a wide degree of acceptance; (2) to acquire engineering data; (3) to define better the critical properties of materials which form the basis for developing methods for establishing criteria of performance; (4) to measure and understand the stable properties of materials which are used to define standards of measurement; and (5) to understand the bulk properties of materials in terms of their microstructure.

Acquisition of Critical Data on Fundamental Physical and Chemical Properties of Matter

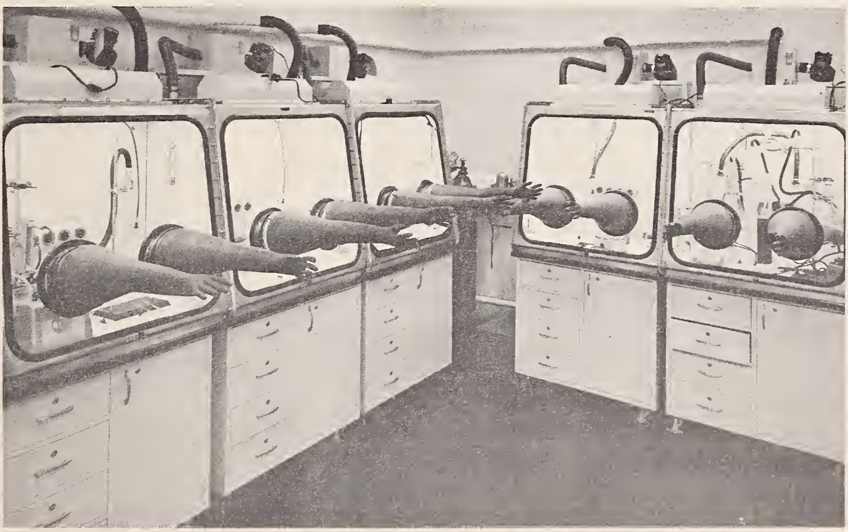
A significant activity in the IMR program is the generation of highly precise and critically evaluated data on the fundamental physical and chemical properties of materials. Reliable data on materials properties are essential to further the scientific and technological progress of the Nation.

In order to give direct support to these several Bureau objectives, the Institute for Materials Research has been organized into six divisions. There is, in addition, the Office of Standard Reference Materials, with its direct service responsibilities. The principal activities of the several divisions are developed in the following chapters.

2.2.1. ANALYTICAL CHEMISTRY

The analytical chemistry laboratories encompass some 30 different analytical competences from activation analysis and atomic absorption to vacuum fusion and x-ray spectroscopy. These competences deal with research in analysis as well as awareness of the practical sample, be it service analysis or standard reference material.

The laboratories are presently concentrating efforts in the areas of trace analysis and high-purity materials, in this way furnishing support for the broad materials program of the Institute of Materials Research. New



Inside view of clean room used in sample preparation for high sensitivity activation analysis. All chemical procedures are conducted inside the glove boxes. **(See page 126)**

activities include inauguration of programs built around the electron microprobe and the spark source mass spectrograph. A considerable extension was also made of the programs in radio chemical analysis, including activation analysis, Mössbauer spectrometry, and radiometric methods.

Activation Analysis Improved. An improvement in the sensitivity of an already highly sensitive analytical method called activation analysis was accomplished through the use of coincidence-counting techniques. The technique discriminates among most of those radioisotopes that do not decay by β-γ_1,-γ_2 in cascade. The decreased background results in an increase by a factor of 1,000 in the sensitivity of the analysis for as many as 20 elements. Efforts are being made to combine the data handling and calculating capability of high-speed digital computers with such physical discrimination techniques in order to broaden the scope of this analytical method.

Improved Mössbauer Spectrometer. A very useful technique for the structural analysis of a material utilizes a type of nuclear gamma-ray resonant absorption commonly called the Mössbauer effect. A decisive improvement in the design of a Mössbauer spectrometer eliminated many precision and accuracy errors that exist in most spectrometers. A Doppler motion-producing transducer was designed to eliminate drifts and distortions in the motion as well as to improve the reproducibility of the motion to better than 0.1 percent. Current studies include application of the technique to the measurement of the quantity of an element in a sample.

Radioistopic Tracers Used for Analysis. The use of radioistopic tracers for the analysis of small quantities of elements is relatively new. The method, which is called radioisotopic dilution, is based upon a measurement of the change in the specific activity (disintegrations per unit time per unit weight of the element) of a radioisotope when an unknown amount of the element being analyzed is added. Bureau personnel modified this method and developed a method of double radioisotopic dilution. Using the Bureau method, sensitivities in the range of 0.1 microgram per gram of sample for the analysis of such elements as silver, cobalt, and iron were obtained. This technique allows any standard industrial laboratory to do many trace analyses with existing laboratory equipment with only the addition of a radiation detector.

Clean Room Constructed. The problem of handling very pure materials without contaminating them with foreign elements is a major one. To reduce contamination in high-sensitivity trace analysis, a clean room was constructed at NBS. A clean room is a laboratory space in which considerable effort is made to eliminate environmental contamination such as dust. Glove boxes are used in the clean room. The air which enters both the glove boxes and the room is passed through high-efficiency filters. The room is used for sample preparation for high-sensitivity activation analysis.

Spark Source Mass Spectrograph Acquired. A commercial spark source mass spectrograph, acquired during the past year, extends considerably the Bureau's capabilities in the general area of trace analysis of solids.

This type of instrument is particularly suitable for a fast survey of elements present in a solid at the sub-part-per-million level, analysis of ultra-pure solids for contaminants, and analysis of the surface of a solid. In present work, well-characterized samples are being used to study the effect of instrumental operating conditions on the reproducibility of analytical data.

Single Reproducible Pulse Obtained with Laser Microprobe. A critical study of excitation of spectra of solid materials by a high-energy pulse of laser light was conducted. In this method the short-time pulse of a ruby laser is focused by a microscope on a very small area of the sample. The energy produced by the laser is sufficient to volatilize any material at the point of focus. A high-voltage spark serves to excite the vapor jet, and the resulting spectrum is photographed by a spectrograph in the usual way.

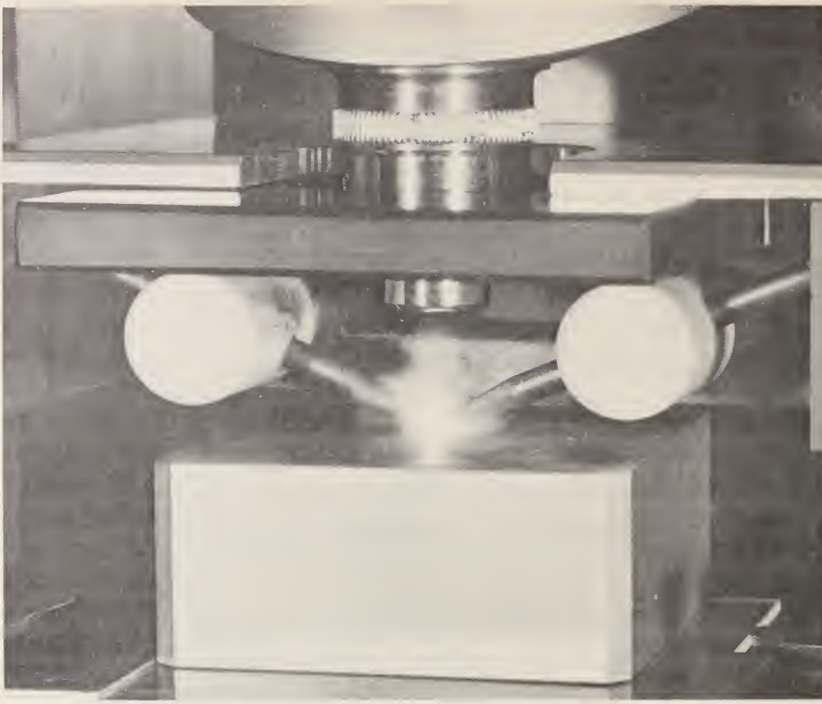
The problem was to obtain a reproducible spectrum so that quantitative analysis of the sample could be made. The major causes for this lack of reproducibility were found to be variations in the energy of the laser pulse and the irregular production of a train of several pulses. Equipment was developed to measure the intensity and time duration of the pulses of light from the laser and modifications were made in the laser system to obtain optimum operation.

A single reproducible pulse is now obtained from each firing of the laser and this is being applied in quantitative analysis. With a single excitation, as little as 0.1 percent of an impurity was detected in a portion of sample weighing 20 nanograms, giving an absolute sensitivity of 20 picograms.

X-Ray Spectrographic Analysis of Solutions. An x-ray fluorescence spectrographic method of analysis was developed and applied to the analysis of brass standard reference materials in solution form. Careful design of the analytical procedure minimized the effects of possible sources of error.

Care is exercised to assure that all solutions are at the same acid concentration and contain the same weight of material per unit volume. The sample cells are designed and filled in such a way that each solution is exposed identically to the x-ray beam. Each sample is analyzed by reference to a series of synthetic solution standards. A new standard is then prepared to have the same composition as the sample; a direct comparison of these two nearly identical solutions provides additional verification of the accuracy of the results. The data obtained compared well with the results of chemical analyses of the same samples, but the x-ray method is considerably faster.

Electron Probe Microanalyzer Extends Capabilities. The Bureau acquired a commercial electron probe microanalyzer for the analysis of extremely small samples such as inclusions in alloys, minerals, and crystals. In this instrument, a beam of electrons is focused onto an area as small as one micron in diameter in order to excite the characteristic x-ray spectra of the elements in the sample. The electron beam can be swept synchronously with the display sweep of an oscilloscope in order to form an image of an area of the sample being studied. This image can be made to represent several aspects of the sample.



Quantitative spectrochemical analysis using a laser pulse and high-voltage spark has resulted in as little as 0.1 percent of an impurity being detected with a single firing. The laser pulse is focused on the block of metal by a microscope. The laser energy volatilizes a small amount of sample which is then excited by a spark discharge between the two pointed carbon electrodes. **(See page 127)**

In one type of display, an image representing back-reflected electrons resembles what is seen through a high-power microscope but can also be made to yield data on composition. Another image can be formed representing the x-ray signal from a particular element in the sample, thus showing the distribution of that element.

More complex displays are possible. For example, an attachment to the electron probe microanalyzer can display areas of the sample falling within a certain range of concentrations for a particular element. The sensitivity of detection depends on the nature of the sample and the element being sought. Typically, the lower limit of detection will be between 0.01 and 0.1 percent, corresponding to a weight of material within the small focal spot of the order of a femtogram. The electron probe microanalyzer extends considerably the capabilities of the Bureau in microanalysis.

Spectra Excited in Controlled Atmospheres. Two similar devices were developed for the excitation of atomic emission spectra in atmospheres other than air. Although arc excitation in controlled atmospheres has been known to improve sensitivity for several years, the advantage of spark excitation in an argon atmosphere is a recent finding. The usual method of excitation in controlled atmospheres has been to enclose the electrodes in a sealed chamber, with considerable time needed to analyze each sample. The two new devices, however, allow the analyses to be performed as quickly in controlled atmospheres as in air.

The two devices, one for arc excitation and one for spark excitation, differ in design but both employ the principle of controlling the atmosphere in the excitation zone by a gentle, tubular flow of gas around one of the electrodes. Spark excitation in an atmosphere of argon was shown to extend the applicability of spectrographic standard samples, since a single set of calibration curves can be applied to the analysis of several related alloys rather than being useful for only a single alloy. Arc excitation in atmospheres of argon, helium, or mixtures of these gases with oxygen often permits a substantial improvement in the sensitivity of trace analysis compared with excitation in air. Studies are presently under way of the complex physical and chemical interactions between the sample, the discharge plasma, and the atmosphere in order to arrive at an understanding of the empirical observations of the effects of changing the gas in the excitation zone.

Special Cast Iron Standards Prepared for the Malleable Research Foundation. In view of previous successful work in the preparation of eight NBS White Cast Iron Spectrochemical Standards, the Malleable Founders Society recently requested the NBS to aid them in the preparation of several special cast iron standards representative of the needs of this group. The first of these standards was prepared with special NBS equipment and under the direction of NBS personnel in the foundry of the Naval Research Laboratory. As the NBS cannot possibly provide all of the standards needed by industrial laboratories, it concentrates efforts on those for use in critical areas of calibration, and encourages and assists outside groups such as the Malleable Research Foundation in the preparation of other standards.

Errors in the Microscopical Measurement of Spheres Studied. In chemical microscopical methods of quantitative analysis, final determination often depends upon the measurement of a volume. Although, it is assumed to be best for the final product to be in the form of transparent spheres, there is a long record of difficulties in the accurate microscopical measurement of the diameter of the spheres. A recent investigation disclosed that the problem originates chiefly in geometrical factors which influence the observer's selection of the position of focus. This error can be as large as 15 percent regardless of sphere size. This increased understanding made it possible to work out several methods by which these errors can be controlled. The accuracy now attained is limited only by the resolving power of the optical system, or about 0.1 micron.

Thermodynamics of Solutions in Heavy Water. Renewed interest is being taken in heavy water (or deuterium oxide) as a solvent, where the two hydrogen atoms of ordinary water are replaced by two atoms of deuterium, the heavier hydrogen isotope.

Corresponding to an acidity scale for solutions in ordinary water (the *p*H Scale), a *p*D scale for deuterium oxide solutions was established. Electromotive force measurements were made over a temperature range using cells with deuterium gas and silver-silver chloride electrodes and a solution of deuterium chloride in heavy water. From these measurements the standard potential of the cell was derived. This was used used along with emf measurements of a similar cell containing solutions of phosphate buffer to determine the acidity function (pD value) of the standard, equimolar (0.025 m) solution of KD_2PO_4 and Na_2DPO_4 in deuterium oxide. The pD value at 25 °C is 7.429, compared with 6.865 for solutions in ordinary water.

p*H *Standards in Partially Aqueous Media Investigated. Standard buffer solutions are available to cover all the usual working range of the pH scale in aqueous solutions. For many industrial and analytical purposes, however, water may not be a suitable solvent. Attention was therefore given to methods of defining acidity scales in a solvent consisting of equal parts by weight of water and methanol. Three buffer solutions—acetate, succinate, and phosphate—in this solvent were investigated and pH values assigned to them over a range of both concentration and temperature.

Preconcentration Polarography. In this new analytical technique, part of an unknown species is concentrated into a stationary mercury drop electrode at a given potential, and then subsequently stripped out using voltammetry with linearly varying potential. The method is being applied to the determination of trace amounts of a number of elements in practical samples.

Magnetic Densimeter Constructed. Densities of pure liquids and solutions over a range of temperatures are needed for the interpretation of a wide variety of physical measurements, including dielectric constants, conductance, and thermodynamic properties of solutions. A magnetic densimeter was constructed which requires as little as 15 milliliters of liquid. A magnetic float in the completely enclosed system is adjusted to buoyant equilibrium by means of an external solenoid. An electrobalance provides a rapid and precise adjustment of the current supplied to the solenoid and permits the calibration of the instrument in reference to a 1-gram mass standard.

Copper-Base and White Iron Standards Issued. Provisional certificates were issued during the year for four types of copper-base spectroscopic standards; free cutting brass, gilding metal, commercial bronze, and aluminum brass. These are certified for copper, zinc, lead, iron, tin, nickel, and phosphorus by chemical analysis. Manganese, silicon, aluminum, antimony, and arsenic were also determined in several standards. There are now seven types of copper-base spectroscopic standards available, making a total of 36 samples.

Four new white iron spectroscopic standards are in preparation. The homogeneity of these samples was checked by chemical analyses of carbon, sulfur, phosphorus, and silicon. In addition, the minor elements tin, titanium, cobalt, aluminum, and arsenic were determined. Major elements will be determined at a later date.

New Uranium and Plutonium Isotopic Standards Issued. A new uranium isotopic standard (U–500) was certified in cooperation with the mass spectrometry laboratory. Synthetic standards at the 50–50 percent level were prepared from highly purified uranium 235 and uranium 238 isotopes to evaluate the uranium 235 and uranium 238 content of the new standard. The limits of uncertainty of the values obtained are believed to be within ± 0.1 percent of the amount present. A new series of uranium 233 "spikes" was prepared for all 16 uranium isotopic standards to obtain more accurate values for the uranium 234 and uranium 236 present. The uncertainty of these values should be within ± 0.25 percent. To obtain better values for plutonium 241 in the new plutonium isotopic standard (Standard Sample 948), americium 241 was removed by ion-exchange and solutions of the americium-free plutonium were prepared for mass spectrometry. The procedure was tested using 1 microgram of plutonium.

High-Precision Coulometry. The research program for the development of very precise and accurate coulometric methods of analysis resulted in a new method for the determination of potassium dichromate. The dichromate is titrated with ferrous ions electro-generated at a platinum cathode by constant-current coulometry. One-half gram samples may be analyzed with a precision of a few thousandths of a percent. The new method permits the standardization of potassium dichromate, a most important chemical oxidizing reagent, with greater reliability than was previously possible. Furthermore, its salient feature, the accurate electro-generation of the ferrous ion, a versatile reducing agent, should find applications in other redox titrations where high precision and accuracy are required.

Analysis and Purification Services Provided. Essential analytical and purification services were provided to various research groups at NBS. During the year 400 requests for such services were completed comprising several thousand individual analyses and purifications. The analytical capabilities were extended by the acquisition of additional polarographic equipment which makes possible minor constituent and trace determinations not readily accomplished by other means. A nuclear-magnetic-resonance (NMR) spectrometer was acquired and a program concerned with analytical applications of NMR was initiated; structural analyses and identifications of organic compounds are also provided as an analytical service.

Development of methods of analysis is a byproduct of this service program. Methods published during the year include a new procedure for the determination of the precious metal rhodium in uranium alloys, and a method for the analysis of zirconia-yttria refractory materials. Advisory and consultative service on analytical chemical problems to other Government agencies is also an ancillary aspect of this program.

2.2.2. POLYMERS

Research is carried out on the constitution and structure of both natural and synthetic polymers. Many of the successful applications of polymer materials, such as rubber, plastics, cellulose, and collagen, depend on the size, shape, distribution, and flexibility of their molecules and on the interactions of these molecules with each other. Hence, a better understanding of the mechanisms involved in forming polymers is being sought to aid in the development of new materials and the efficient utilization of those now available.

Services are also provided to Government and industry in developing and maintaining adequate measurement and materials standards. In this program, standard samples or reference materials having accurately known properties are distributed to facilitate the calibration of measurement systems, including instruments and test methods. These include the development of a series of standard polymers with precisely known molecular weight distributions.

The Department of Defense sponsors work in the development of fluorocarbon polymers and in special techniques of polymerization; the National Aeronautics and Space Administration assists in the study of polymer stability; and the Advanced Research Projects Agency supports work on the crystallization of polymers. The American Dental Association and the Federal dental services continue their support of a cooperative program to improve dental materials and equipment or to develop new ones for use in restoring teeth. The Bureau also assists other Government agencies in developing standards and specifications for products made from polymers and intended for Government use.

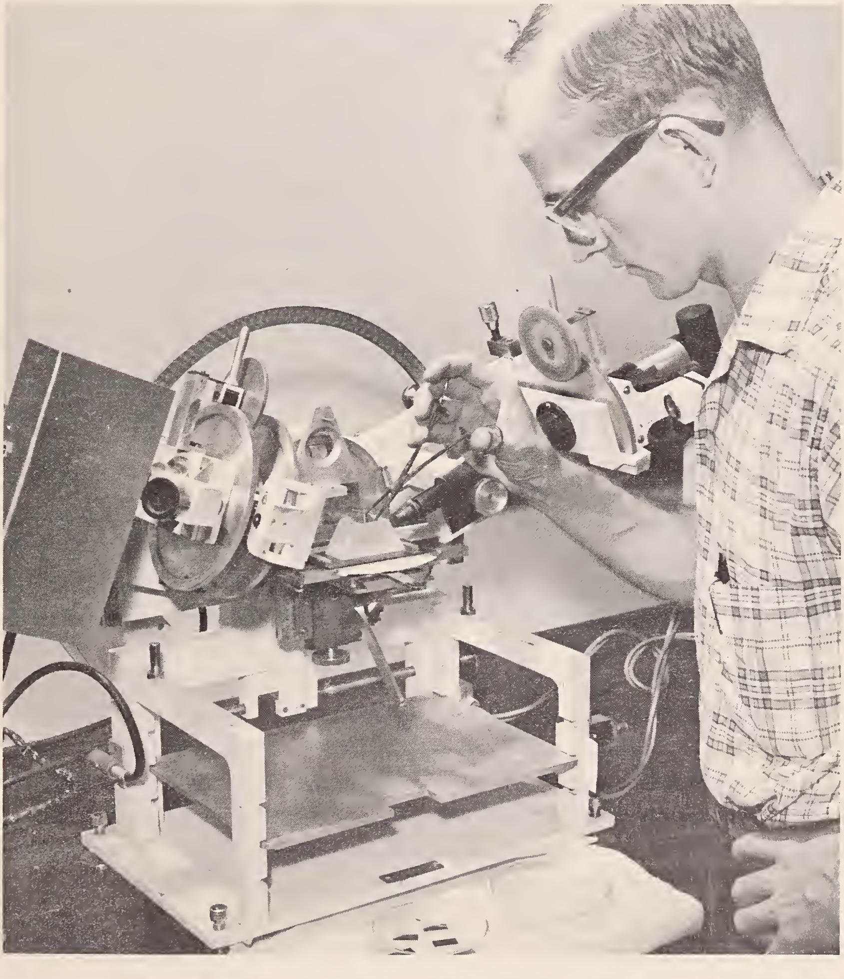
Cooperative Intramolecular Transition Found in a Synthetic Polypeptide. Previous work at NBS and elsewhere has indicated that synthetic poly-L-proline may exist in either of two forms, differing in crystallographic structure as well as in other properties. Induced transformation between these two forms was studied by measurement of the optical rotatory power of dilute solutions of the peptide. The results, augmented by infrared spectroscopy and crystallographic observations, led to the conclusion that the two forms are configurationally homogeneous structures whose imide linkages are respectively in either the *cis-* or *trans-*planar configuration, the transition between them consisting of repeated *cis-trans* isomerizations along the backbones of individual peptide chains.

In contrast to the familiar helix-coil transitions observed in many polypeptides, the present system is a helix-helix transition. If the former is considered as the one-dimensional analog of melting, the latter is the analog of solid-state transformations between different crystalline modifications of a single substance. Of particular interest are (1) that the two forms are helices of opposite sense, i.e., right- and left-handed, and (2) that the transition between them is so abrupt as to suggest the existence of a cooperative effect which, in the limit of a complete all-or-none mechanism, leads to a first-order one-dimensional phase transition.

Stress Found Proportional to Double Refraction in Amorphous Polymers. Large polymer molecules characteristically have the ability to assume many conformations because of rotations of molecular segments about the valence bonds. The elongation of these molecular chains forces transitions to take place between the different conformations, and the increase in free energy of this process is responsible for a retractive force.

Not only are the chains stretched out, they also become partly oriented. If the chain bonds are optically anisotropic, this orientation should be directly related to double refraction of the chain.

For simple polymers, much is already known about their structural properties such as bond lengths, bond angles, and rotational angles for which the potential energy is a minimum. To make calculations, however, for a rubberlike material that consists of many molecular chains crosslinked to one another, it must be assumed that the intermolecular forces do not change materially on stretching and that the only contributions to the elongation come from the intramolecular forces. Calculations based on these assumptions yielded a factor of proportionality between stress and double refraction for an amorphous polyethylene sample. These results, in excellent agree-



The thickness and refractive index of adsorbed polymer film not more than a few Angstroms thick can be measured by ellipsometric techniques, thus providing a better understanding of the constitution and structure of both natural and synthetic polymers. **(See page 135)**

ment with published values in the literature, indicate that the supposed mechanism underlying the stretching process is correct, and they also provide a better understanding of the relationship between chain structure and elastic properties.

Polypropylene Crystals Studied. The formation mechanism of monoclinic spherulites of isotactic polypropylene was investigated. Specimens were crystallized from ¾ percent solutions of the polymer in amyl acetate in the temperature range 110 to 115 °C. An analysis of the resulting fine structures showed them to be dendritic crystals. Narrow (150 to 200 Å), diagonally oriented crystal branches were found to be lamellar when viewed along the crystal plane. On the basis of these results, coupled with information on the molecular orientation in the crystals derived from another study, it was concluded that the chain molecules in their constituent branches are regularly folded and that the extended interfold molecular segments are oriented preferentially parallel to the plane of the crystal and normal to its longer axis.

Crystalline Polymers. A recent study of isotactic polypropylene samples of varying degrees of crystallinity and morphology indicates that differences found among these materials depend almost entirely on the method of comparison. For example, when the various samples were compared at equivalent macroscopic strains, the resulting behavior was almost independent of morphology and crystallinity. On the other hand, when they were compared at equivalent macroscopic stresses, the extent of relaxation decreased uniformly as crystallinity increased. This behavior is explained on the basis that the crystalline polymer is a composite material consisting of crystalline regions and some less perfectly ordered (amorphous) regions, both of which may relax but to different extents.

Thickening of Chain-Folded Crystals. Low-angle x-ray measurements were made on bulk polyethylene at various temperatures below the melting point while crystallization was occurring. As had been predicted earlier on various grounds, it was found that the chain-folded lamellae slowly thickened, for example, approximately doubling their initial thickness in a thousand minutes at 128 °C. This work is of significance in the explanation of the melting and annealing behavior of crystalline polymers.

Lattice Parameters of a Copolymer. Recent measurements showed that the lattice parameters of a copolymer of tetrafluoroethylene and hexafluoropropylene are larger than those of polytetrafluoroethylene at all temperatures between −196 and 25 °C. Thus the lattice of the copolymer is larger than that of polytetrafluoroethylene, even below the first-order transition temperatures of about −50 °C in the former and between 15 and 30 °C in the latter. It therefore appears that the larger size of the copolymer lattice at room temperature is not the result of heating above the transition temperature where lattice parameters and thermal coefficients of expansion increase. Instead, the results support the concept that the comonomer units are included in the lattice as point defects and thus enlarge the lattice.

Mechanism of Polymer Adsorption Investigated. Unlike small molecules, large polymer chain molecules may have only relative few of their segments adsorbed on a solid surface. These segments can then act as anchors for the rest of the molecule, which is in the shape of loops dangling in the solution. Several theories have been advanced to describe this arrangement but the underlying assumptions have not been completely satisfactory.

Recent NBS work shows that low surface adsorption may be described by a mathematical model virtually identical to the one used to describe the helix-coil transition occurring in DNA (deoxyribonucleic acid), the well-known molecule of biological importance. Consequently, stiff chains should be adsorbed with most of their segments in contact with the surface, and the loops should be sparse and short. Flexible chains should be adsorbed with only a few anchoring segments, if the surface exerts weakly attractive forces, and the loops should be large. For strongly attractive forces, flexible chains should tend to flatten out at the surface. Experiments now under way to verify this theoretical work may provide a deeper insight into the mechanism underlying polymer adsorportion.

Polymer Properties Statistically Calculated. A theoretical model, based on the theory of absorbing Markov chains, was developed to calculate the various thermodynamic functions of a single polymer chain resulting from intramolecular interactions. The idealization of a polymer chain as a Markov-type chain imposes a restriction on the type of intrachain interactions, so that only short-range interactions can be considered. Hence the new model applies especially to extended polymer chains, with net repulsions between its various elements, for example, polyelectrolytes or polymers in good solvents.

By use of the Monte Carlo technique, a computer program was designed to calculate the stretching of model polymer chains resulting from the increase in the effective free volume of a single polymeric element.

Compressibility of Natural Rubber. The specific volumes of unvulcanized natural rubber and of a peroxide-cured vulcanizate were measured at pressures from 9.8 to 4900×10^4 newtons per square meter (N/m^2) at temperatures from 0 to 25 °C. Observations on mercury-filled dilatometers were made through a window in the pressure system. An empirical equation representing the observations over the range investigated was found and the constants evaluated. Calculations of values of compressibility (and its reciprocal, the bulk modulus), "internal pressure," bulk wave velocity, difference between specific heats, and several other physical properties were in reasonable agreement with those obtained by direct observation by other workers.

Ultracentrifuge Used to Study Polymer Sedimentation. Information was obtained in recent ultracentrifuge experiments concerning the dependence of the sedimentation coefficient of polystyrene on concentration at temperatures around the theta point where the solution is thermodynamically

An electronic thermogravimetric balance used to detect changes in weight of coordination polymer samples as they are heated in a vacuum furnace (extreme right). The measurements obtained are an indication of polymer thermal stability. **(See page 138)**

ideal. The study showed that the concentration dependence does not disappear at the theta point but at a considerably lower temperature. This behavior is attributed to a balancing of hydrodynamic and thermodynamic interactions of the polymer molecules. The data were shown to be consistent with a recent theory predicting this behavior.

Heat of the Vulcanization Reaction. Quite a discrepancy exists in the literature as to the heat involved in the rubber-sulfur vulcanization reaction. Earlier calorimetric work at NBS found heat to be liberated at all concentrations of sulfur, but other investigators claim that no heat is liberated unless at least 7 or 8 percent of sulfur is reacted with the rubber.

Recent experiments were conducted on the rubber-sulfur system with a differential thermal analyzer, an extremely sensitive instrument to heat changes during a chemical reaction. The results give positive evidence that the vulcanization reaction is exothermic at all percentages of sulfur, verifying the findings of the earlier NBS work.

Fluorine Chemistry. New highly or totally fluorinated aromatic monomers were synthesized for the purpose of preparing thermally stable polymers. One class, including such monomers as 2,3,4,5,6-pentafluorostyrene, α-hydroheptafluorostyrene, and perfluorostyrene, is designed to yield polymers that have a pendent perfluorophenyl group along the polymer backbone. A second class, typified by *p*-hydroxyheptafluorotoluene, is designed to incorporate a perfluorophenylene group in the polymer chain.

Efforts to prepare a material of high thermal stability and good elastomeric properties were continued by the preparation and polymerization of perfluoropentadiene, the first completely fluorinated rubber to be reported. Techniques and chemistry that will permit preparation of all terminal dienes from $C=4$ to $C=24$ were developed.

Polymer Stability to Radiation. A thermal conductivity cell sensitive to 0.01 mole percent of volatile products was used to study the decomposition of polytetrafluoroethylene exposed to ionizing radiation in a flowing helium stream. Measurements were made in the temperature range from 330 to 460 °C and at dose rates of from 0.2 to 10 megarads per hour. The results of this work, together with thermochemical data, indicate a very high activation energy for polymer chain termination.

Techniques Devised to Study Polymer Oxidation. Two techniques were devised to measure the oxygen consumption of polymers as a function of temperature. The first is a gas chromatographic approach which uses a molecular sieve to separate the various components in samples of the atmosphere surrounding the polymer. Measurements of the relative amounts of oxygen and nitrogen in samples of this atmosphere made at various time intervals at a given temperature permit calculation of polymer oxygen consumption rate. Measurements at different temperatures give the apparent activation energy for the reaction, which is indicative of polymer resistance to oxidation.

Polarography is used in the second technique, permitting the investigator to follow oxygen consumption directly and continuously. In this method, a commercial polarographic cell makes use of silver and gold electrodes and a special diffusion membrane to obtain high selectivity for oxygen analysis.

Polymer Degradation. In a recent investigation, dextran triacetate was found to exhibit greater stability than dextran to gamma radiation. The post-irradiative molecular weight drop in dextran was more rapid in the presence of moisture, indicating that some type of oxidative cleavage by hydrogen peroxide is formed from the radiolysis of water. An insoluble crosslinked dextran, similar in appearance to chemically crosslinked dextran, is formed at high concentrations and moderate dose rate in vacuum.

The thermal decomposition of polystyrene in tetralin solution was also investigated between 253 and 297 °C. The percentage of material volatilized and the decrease in molecular weight were found to depend on concentration, indicating that the scavenging effect of the tetralin is not complete under these conditions. A rapid initial degradation, amounting to only 0.11 scissions per initial chain, was detected at the lower temperatures. An activation energy of 25×10^4 J/mole (60 kcal/mole) was obtained from the initial rates of the subsequent degradation. Hence, the rapid decrease of molecular weight of polymeric materials cannot be based on the theory of "weak links" in the molecular chain.

Properties of Coordination Polymers. Coordination polymers formed by the combination of *bis*-bifunctional derivatives of 8-hydroxyquinoline with metal ions are an important new class of polymers having potential space applications. To obtain data on the properties of such polymers, an organic ligand, 5,5′-[methylene-(*p*-phenylenenitrilomethylidyne)] *di*-8-quinolinol was recently synthesized by the use of a Schiff-base bridging group to link two 8-hydroxyquinoline molecules. This ligand, when reacted with some first-row transition metal ions, yielded highly colored insoluble coordination polymers having high thermal stability in vacuum. Data derived from the study on the relation between decomposition temperature and the metal incorporated in the backbone of the polymer chain, coupled with studies of molecular structure, will make it possible to explain and perhaps control the behavior of these polymers.

Microradiography of Roofing Materials. Microradiography was recently used to determine the distribution of reinforcing materials in asphalt films and mats, as well as the origin and development of failures in shingles and other structures. The method not only reveals many details of the mechanism of deterioration; it is also often able to disclose intrinsic weaknesses in design or formulation before they become apparent by other methods of analysis.

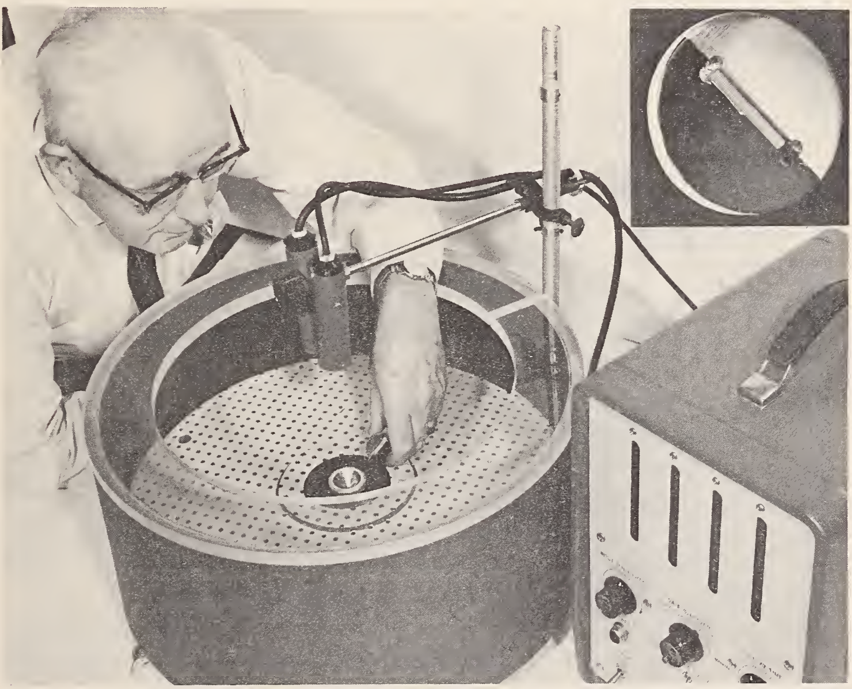
Centrifugal Method for Measuring Tensile Strength of Dental Amalgam. A centrifugal method of stressing specimens was developed. It applies the Beams (University of Virginia) method of driving a rotor by air. The stress (S) for any size specimen can be computed by the simple formula $S=2\pi^2Df^2L^2$. Hence, with density (D) and length (L) of a specimen known, only the frequency of rotation (f) needs to be observed. With this method, flow of a material under tensile stress can be determined at a constant rotation over a period of time. Tests made on dental amalgam show tensile strengths of from 10×10^6 to 69×10^6 N/m^2 (1,500 to 10,000 psi) in specimens ranging from 1 hour to 1 day old.

Properties of Tooth Structure. A method developed for measuring the shear strength of human tooth dentin requires the use of sectioned molars parallel to the biting surface and a hardened steel punch with a diameter of 6.35 mm (0.250 in.). The maximum load the specimen supports divided by the shear area (specimen thickness times punch circumference) gives the shear strength. The specimen thickness, between 0.26 and 1.14 mm (0.010 and 0.045 in.), did not appear to be correlated with the average shear strength of $98 \pm 16 \times 10^6$ N/m^2 (14,200$\pm$2,300 psi). However, the variance was considerably smaller in data obtained on test specimens between 0.55 and 1.0 mm (0.021 and 0.039 in.) in thickness.

The adsorption of gases is being used as a measure of the "inner surface area," hence, the porosity of teeth. Measurements made on dentin samples shortly after extraction of the teeth and then again after one year in cold storage gave the same value of 10.5 square meters per gram. When the organic matter was extracted from these samples with ethylene diamine the area increased by more than an order of magnitude to 124 square meters per gram.

A proposed mechanism for the growth of tooth and bone crystallites was developed and is being investigated. The crystallites are principally hydroxyapatite, $Ca_5OH(PO_4)_3$. A unique feature of the mechanism is that the growth apparently involves the initial deposition of another crystalline calcium phosphate, octacalcium phosphate, $Ca_8H_2(PO_4)_6 \cdot 5H_2O$. This departure from the previously accepted growth mechanism introduces new factors which should lead to a better understanding of the beneficial effect of fluoride in preventing caries.

Rheological Behavior of Dental Amalgam. A study of the rheological behavior of dental amalgam (a mixture of mercury and powdered silver alloy used as the restorative material in about 75 percent of all dental fillings) was made by means of tensile creep tests. The tensile strain developed was found to be a function not only of the applied stress but also of length of time of stress application. Amalgam was shown to exhibit (1) strain hardening; (2) elastic deformation; (3) retarded elastic deformation; and (4) viscous deformation. The viscoelastic data obtained from the study



A new centrifugal method for measuring the tensile strength of dental amalgam allows the flow of the material under stress to be determined over a period of time. Insert shows top of rotor with specimen in place. **(See page 138)**

were used to calculate tensile stress-strain curves which agreed with those obtained experimentally at various stressing rates.

Reinforcement of Dental Polymers. Polymer materials used to restore or fill teeth match natural teeth closely in appearance but have other properties (such as a high coefficient of thermal expansion) that limit their usefulness. A study was made of the feasibility of employing fused silica particles to reinforce dental polymers and to improve their properties. The results show that optimum conditions for reinforcement include (1) use of a chemical coupling agent such an an organofunctional silane; (2) spherically shaped particles; (3) intermittent grading of particle sizes to reduce the amount of polymer; (4) fine particles to increase strength; and (5) addition of certain glass powders to obtain visual and x-ray opacity. Monomers having low polymerization shrinkage and other desirable features were produced for use with these powders. Compared with previously existing dental filling resins, the resulting materials have an improved thermal expansion coefficient, compressive strength, and modulus of elasticity.

2.2.3. METALLURGY

The metallurgy program has two main parts, both aimed at solving problems important to the national economy. Mechanical characteristics and resistance to corrosion are the two most important properties of metals, which are used mainly as structural materials. The basic understanding of these two phenomena in metals is therefore emphasized.

Metallurgical research is focused on the mechanical properties of metals, corrosion, metal crystal growth, and the physics of alloys. This work includes studies of creep, fatigue, notch sensitivity, stress corrosion, nucleation and growth of oxide films, the kinetics of metal crystallization, electrolytic and vapor decomposition techniques for producing metal coatings, and the electronic configurations in metals. The research stresses the relationships between the properties of metals and crystal defects and microstructures as observed by x-ray and electron diffraction, transmission and replica electron microscopy, light microscopy, x-ray diffraction topography, and electron probe microanalysis.

Analyses are made of the service failures of aircraft for the Bureau of Naval Weapons and the Civil Aeronautics Board. Consulting services on corrosion are provided various agencies of the Department of Defense and the National Aeronautics and Space Administration. Critical evaluation of data on diffusion in metals is carried out and highly pure metal crystals are prepared. Various other metallurgical services are provided to Government agencies on request and in collaboration with other NBS Institutes.

Effects of Notch Geometry Investigated at High Temperature. The effects of notch geometry (depth, included angle, and root radius) upon the tensile, stress-rupture, and creep properties of a high-strength titanium alloy at temperatures up to 1200 °F were investigated. The strength of the alloy was increased and ductility decreased with decrease in notch angle or root radius and with increase in notch depth. Preliminary results in the creep and stress-rupture tests indicate that ductility increases with increase in temperature and with a decrease in strain rate. The origin and propagation of fracture are affected by the notch geometry of the specimens and the test temperature.

Precision Gage Block Materials. Several combinations of materials and treatments yielded a gage-block dimensional stability better than 0.2×10^{-6} in./in. in a year, and a few combinations, better than 0.1×10^{-6} in./in. in a year. Additional observations were made on promising types of experimental gage blocks now under investigation to establish their long term stability (see p. 60). New materials and treatments were investigated to determine their suitability for inclusion in the gage-block program and many were selected for test. Several factors that are believed to influence stability are being studied in an effort to better understand and control the causes of instability.

Deformation of Metals Studied. The effect of multiaxial stresses induced by notches on the tensile deformation and fracture characteristics of a 310 austenitic stainless steel were studied. Severe strain and work hardening in the highly stressed region near the root of the notch initiated a crack at relatively small average strain and at stresses considerably below maximum load; these cracks then propagated slowly until final rapid fracture occurred at much larger strains. This mode of failure depends mainly upon the radius at the root of the notch and not its depth. For this particular steel, the minimum notch radius should be greater than 0.05 inch to avoid this type of crack initiation and growth.

Slack-Quenching Effects Studied. Studies of the quantitative effect of slack quenching upon the mechanical properties of three steels of medium hardenability (4140, 5140, and 8640) are in progress. It is generally believed that the presence of a slack-quenched structure is detrimental to the optimum mechanical properties of steels. Preliminary data indicate that this belief is generally valid; however, sometimes small amounts of slack-quenched structures have no detrimental effect and, under certain restrictive conditions, the presence of substantial amounts of these structures appear to improve mechanical properties.

Metal Fatigue. Present research is directed toward elucidating the effect of atmospheric environment on fatigue and the relationship between cracks and fatigue. A recent study of the effect of a fatigue crack on the strength of an aluminum alloy used the beginning of gas evolution as an indicator of the inception of cracking. Cracked specimens show a fatigue strength of only about 40 percent of similarly stressed but uncracked specimens.

Nuclear Magnetic Resonance. Information can be obtained on the electronic structure of alloys by analysis of nuclear magnetic resonance linewidths, quadrupole effects, and Knight shifts of both the solvent and solute nuclei in the same alloy. Hence, the nuclear magnetic resonances of Pb^{207}, Bi^{209}, In^{115}, Hg^{199}, Sb^{121}, and Tl^{205} in Pb-based primary solid

Notch geometry is extremely useful in studying the origin and propagation of metal fractures. Here, a tensile specimen of 310 stainless steel cracks under a true strain of 0.22 (left). Crack has grown under strain of 0.8 (right) just prior to the rapid final fracture of the specimen. **(See page 140)**

solutions were studied in great detail. The Pb^{207} results showed that the change in Knight shift in composition is small in contrast to monovalent and divalent systems. In the other work, no evidence of pronounced quadrupole effects was obtained for the solutes in the alloys. Since both large changes in Knight shift and large quadrupole effects in alloys have been interpreted in terms of long-range charge oscillations around the solute atoms, it may be concluded that the charge oscillations in the Pb alloys are less effective than has been found in other cases.

The existence of a nuclear magnetic resonance linewidth anomaly in lithium has long puzzled investigators. In a recent study, a multiple pulse nuclear magnetic resonance technique was used to disclose that the anomaly is an experimental one and it is associated with the diffusion effect in large magnetic field gradients. These field gradients exist as a consequence of the bulk magnetic susceptibility of the lithium metal powder.

Highly Pure Metals and Alloys Prepared. During the preparation of a series of lead-tin alloys, the tin in solid solution under nonequilibrium conditions was retained long enough to make nuclear magnetic resonance measurements. The powdered samples were reheated and then quenched in ice water. At the request of the NBS solid state physics laboratory, three gold-iron alloys with a small controlled addition of iron were prepared in the form of 10-mil wire for the study of magnetic ordering in dilute solid solutions of iron in gold. Iron-nickel alloys were also prepared for the Geological Survey and intermetallic compounds of niobium and iron for the Naval Research Laboratory.

Dislocations in Metals. An investigation of the nucleation of gold deposited on cleaved zinc surfaces was completed. Decoration of surface steps was observed in some cases, and the distribution of nuclei was found to depend on substrate temperature. Observations of the nuclei were made by transmission electron microscopy through the thin zinc substrate. Determination of the stacking fault energy in a series of dilute silver alloys was undertaken, and preliminary observations of dislocation structures in low stacking fault energy Ag(Sn) alloys were made.

Stacking Fault Theory Being Developed. The stacking fault energy in many face-centered cubic (FCC) alloys is lowered by alloying; hence, thermodynamic equilibrium requires some segregation of solute atoms in the stacking faults to lower the total free energy. In FCC crystals, a total dislocation may lower its energy by splitting into two partial dislocations connected by a stacking fault. Thus the separation between partial dislocations is increased and the faulted area is enlarged. A general theory is being developed to describe these phenomena. This theory may have important applications in the measurement of stacking fault energies by means of electron microscope observations of dislocations, and in theories of the mechanical properties of materials.

Electron Probe Modified. The Bureau's electron probe microanalyzer was recently modified to make it a more versatile instrument. An increased x-ray takeoff angle makes possible more accurate analysis of the light elements. An improved light optics system was installed, together with an enlarged specimen chamber. Facilities to perform Kossel line studies were added. New spectrometers are being built for the instrument so that quantitative microanalysis may be made of elements down to sodium and ultimately down to carbon.

X-Ray Diffraction Studies. Residual microstrain measurements were made in individual grains of a deformed coarse-grained polycrystalline aluminum specimen. By means of x-ray diffraction techniques employing photographic film and a counter diffractometer, the effect of residual stresses upon the spacings between the planes of atoms within the metal grains was observed. The existence of preferred orientations in electrodeposited copper samples was also observed.

Intermetallic structures of the niobium-tin system were studied on small single crystals isolated from tin amalgams. Crystals isolated from amalgams quenched from 1000 °C had the β-W type structure and were found to be ordered. Crystals isolated from 800 and 850 °C quenches consisted of Nb_2Sn and had the $CuMG_2$ type structure. Crystals of the Ni_3Sn_4 type (monoclinic) and W_5Si_3 type (tetragonal) were also isolated in furnace cooled amalgams. Isolated single crystals of Ag_3Sn were found to be of the Ni_3Ta type structure, which requires doubling of the unit cell.

Micrographic Analysis Performed by Computer. The Bureau's experimental computer program for the automatic quantitative analysis of micrographs excited widespread interest during the year. A chromosome matching program based on the NBS model is being developed elsewhere, and NBS is studying nerve cell tissues by means of the technique. Micrographs are being prepared of photographic emulsions and ceramic materials for computer measurement. The technique showed that excessive heat treatment of a niobium-tin alloy apparently caused inferior superconducting properties to develop. An improved program for the NBS PILOT computer, now being completed, will respond to instructions given in normal English sentences and will accept data obtained from grey-scale pictures up to 20×24 cm in size.

Polarization Technique for Measuring Corrosion Rates Applied to Iron-Nickel Alloys. A polarization technique was used to study the corrosion of a series of iron-nickel alloys. The corrodent was Washington city water containing 3 percent sodium chloride. Results thus far show a marked reduction in the corrosion rate of alloys containing 40 percent or more of nickel, with a further reduction in alloys containing 65 percent or more of nickel. When the nickel content is 80 percent, the corrosion rate is considerably less than 1 percent of that of the unalloyed iron exposed to the same corrodent.

Surface Studies in Corrosion. The initial formation of oxygen films on iron surfaces was studied by means of elliptically polarized light. The growth rates of the films were determined during the first fractions of seconds by measurements of film thickness and optical properties. The first stage is an anodic process lasting about 0.2 to 0.4 seconds during which no film growth is detected. This is followed by a rapid linear growth and to different logarithmic growth processes. The latter stages of film growth are the results of the movement of metal ions through the film under the driving force of an electric field.

Steel Pilings Examined. Thirty-five steel piling structures in service for from 5 to 50 years were inspected for the American Iron and Steel Institute. They showed practically no damage below the water line. These findings agree with those previously made, namely, that steel pilings driven into the ground are not materially affected by corrosion, probably because of the lack of oxygen under such "undisturbed soil" conditions.

Stress Corrosion Cracking. The effect of the Cl ion on the stress corrosion cracking of stainless steel, type 304, was investigated. The duration of the exposure periods to failure differed with specimens exposed to $MgCl_2$ and LiCl, even though the Cl ion, the stress, and the temperature of the corrodent were kept constant. Bubbling oxygen into the corrodent profoundly accelerated the corrosive attack. This result confirms earlier findings which demonstrated the importance of the presence of oxygen in the initiation and propagation of stress corrosion cracks.

Corrosion Failure of Electroplated Coatings. NBS and the American Electroplaters' Society are engaged in a joint study of the galvanic effects associated with the corrosion failure of electroplated coatings. One aspect of this work involves the electrolytic cell formed when a layer of metal is exposed at the base of a pit in an overlaying metallic coating. To simulate a pit in a nickel coating on steel, a small hole was drilled in the center of a sheet of nickel and an iron wire was cemented into the hole so that one end of the wire was flush with the surface of the nickel. A low-resistance ammeter was connected between the nickel and iron wire and the cell was exposed to a corrosive environment.

During a 1-year outdoor exposure, currents as great as 1½ microamperes were observed, though usually they were in the range of 10 to 100 nanoamperes. These values, corresponding to current densities of about 4 milliamperes per square centimeter (ma/cm^2) and 0.02 to 0.2 ma/cm^2, were converted to corrosion rates (depth) of 108 μ/day and 0.7 to 7 μ/day, respectively. Dew, rain, and melting snow yielded similar currents and the larger currents were observed in warm weather.

Properties of Electrodeposited Copper. Measurements of the physical and mechanical properties of electrodeposited copper are in progress. The deposits are made from conventional copper sulfate-sulfuric acid solutions under a variety of conditions of temperature, current density, and concentration of salt and acid. The results thus far show that tensile strength increases with current density and decreases with increase in temperature

Transmission electron micrograph of extended dislocations in a stainless steel sample. The low stacking fault energy in this material permits observation of the faults (exhibiting interference fringe contrast) associated with the dislocations. Magnification 120,000. **(See page 143)**

or concentration of bath constituents. The stronger electrodeposits have about the same strength as annealed wrought commercial copper but are not as strong as hard-drawn commercial copper. Values of elongation of copper electrodeposits parallel their tensile strength values. Variations in internal stress also parallel variations in tensile strength. The maximum internal stress thus far found is not large enough to cause difficulty in engineering applications of copper electrodeposits. This project is supported jointly by NBS, the American Electroplaters' Society, and the International Copper Research Association.

Chemical Deposition of Tungsten from the Vapor Phase. Some time ago the Bureau developed a method of producing tungsten in the form of thick coatings by passing tungsten hexafluoride (a gas) and hydrogen over an object heated to about 650 °C. A rate of deposition of more than 25 microns per minute was obtained and smooth deposits up to 3 mm thick were produced. The process permits the production not only of coatings on objects but also of complete items of tungsten. For the latter, a master of copper or nickel is first formed and then coated with the requisite thickness of tungsten. The copper or nickel is then subsequently dissolved with nitric acid, which does not attack tungsten.

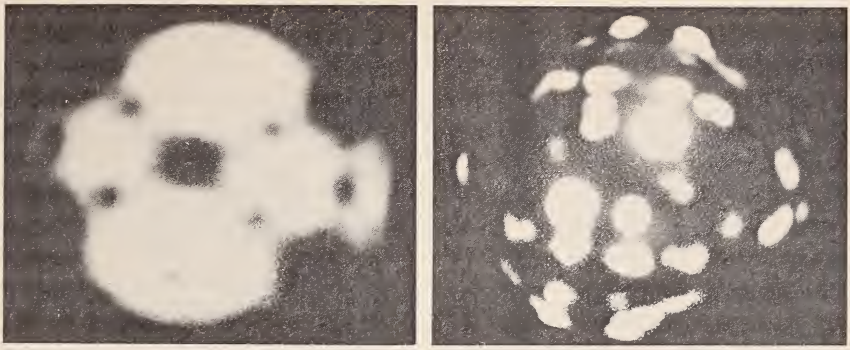
An investigation supported by the Air Force showed that the rate of deposition of tungsten increased with the concentration of tungsten hexafluoride, and that an oxygen content equal to about 1 percent of the tungsten hexafluoride content had a noticeable effect in lowering the rate of tungsten deposition. Hydrogen fluoride, a product of the reaction, inhibited deposition and in some instances stopped it altogether.

The hardness of the large columnar-grained material most commonly obtained was 42 Rockwell C, comparable to the hardness of commercial tungsten rod. The fine-grained material obtained in the presence of excess of tungsten hexafluoride had a hardness of 62 Rockwell C.

Galvanostalametry. Efforts to devise means for extending electrochemical investigations led to the development of a new technique called galvanostalametry, which is based on the tensile strength of liquids. This little-known property of liquids is manifested upon suspension of a column of liquid in a vertical glass tube terminating at the lower end in an evacuated reservoir. When an indicator electrode is sealed at the top of the column and an auxiliary electrode incorporated in the reservoir, the passage of a current which produces gas at the indicator electrode results in an abrupt fall of the metastable column.

Investigations showed that the critical electric charge required to drop the column is a quantitative function of the electrolyte composition, electrode area, and other variables of the system. The method was used to study oxygen and hydrogen overvoltages, to obtain information on the formation rate of hydrogen and oxygen gases from their respective ions, and to determine copper sulfate concentration.

Kinetic Equations for Diffusion in a Driving Force. When diffusion occurs by a vacancy mechanism, the individual atoms do not follow a



Study of mercury nucleation by electron field emission provides considerable information on the mechanical properties of metals. (Left) Emission pattern from clean tungsten tip. (Right) Pattern from same tip after nucleation of mercury crystallites (magnification 300,000). **(See page 147)**

random walk; hence, accurate kinetic equations for diffusion in a driving force have been difficult to obtain. This difficulty was overcome by a consideration of planar diffusion along particular crystallographic directions and by use of effective jump frequencies. With this approach, accurate kinetic equations having the same form as those of a one-dimensional random walk were obtained. These equations can easily be modified to treat diffusion in a driving force.

Stacking Faults in High-Temperature Creep. Several studies are planned to investigate the influence of stacking fault energy on the mechanical properties of face-centered cubic metals. The activation energy for high-temperature creep will be determined for a series of Cu-Ge alloys of varying stacking fault energy. Electron microscope and etch pit studies will be made to ascertain where the rate-controlling process for high-temperature creep occurs and the influence of stacking fault energy upon the mode of deformation. The extent of primary creep and the minimum temperature at which the activation energy becomes that of self diffusion will also be determined.

Kinetics of Whisker Growth and Evaporation. In studies of the kinetics of whisker growth from the vapor phase, it is assumed that growth takes place by adsorbed atoms diffusing along the whisker surface and depositing on the whisker tip at the growth step of an emerging screw dislocation. The partial differential equation describing the growth rate as a function of vapor pressure, evaporation time of adsorbed atoms, whisker dimensions, and surface diffusion coefficient is complicated by a moving boundary condition. A pair of implicit integral equations were therefore derived to permit numerical computation of the growth curve by the technique of successive approximations. In addition, the asymptotic behavior of the growth curve derived for long times was shown to be linear.

Nucleation Studied by Electron Field Emission. The heterogeneous nucleation of mercury onto tungsten field emitters is being studied by electron field emission. Nuclei were observed at a substrate temperature of 100 °K and at a mercury vapor pressure of 5×10^{-8} torr. The time required to form the nuclei was measured and a critical coverage calculated. Nucleation time is also being measured as a function of emitter temperature and vapor pressure.

Metal Single Crystals. In studies of the origin of defects in metal single crystals grown from the melt, thin, tapered crystals of high-purity aluminum were "pulled" at varying speeds and temperatures. X-ray topographs showed that the amounts of both dislocations and segregated impurities seem to decrease near the tip where the crystal diameter is less than 0.5 mm.

2.2.4. INORGANIC MATERIALS

The need for more precise information on the preparation and properties of inorganic materials in modern technology is increasing rapidly, and the Bureau pursues an active program in these areas. Studies are under way on the nature of the vapor phase of materials at high temperatures, the nature and properties of the vitreous state, inorganic synthesis, and on the basic aspects of crystal nucleation and growth. Phase relations of oxides—particularly of the rare earths, bismuth and boron—magnetic properties of complex boron compounds, and the electron-spin-resonance of transition metal complexes are subjects of further studies.

Knowledge of the atomic arrangement of solids is fundamental in understanding the properties of materials. NBS programs include both the determination of key structures and the development of methods of measurement and instrumentation leading to increased speed and accuracy of structure determinations and facilitate such studies under special conditions of temperature and pressure.

There has been increased recognition of the profound effect that departure from perfection in crystals has on their properties. The properties affected, which include electrical resistance, dielectric loss, internal friction, and sinterability are often of considerable commercial and scientific interest. NBS is therefore actively studying the effects on these properties of both point defects and dislocations.

The Bureau is also active in programs of standardization, data production, evaluation, and collection. Activity in these fields includes publication of accurate x-ray powder patterns for chemical analysis, compilation and measurement of the melting points of refractory oxides, production of standard glasses for viscosity measurements, collection of phase diagrams of inorganic materials, and production of bibliographies of high-temperature research.

Growth of Inorganic Compounds Investigated. The Bureau, supported in part by the Advanced Research Projects Agency, was active in the study of methods of inorganic crystal growth. Various methods were involved because of the range of properties of the crystals and their intended use.

A high-frequency induction heater (45 to 90 MHz) was used successfully to melt the high-resistivity oxides TiO_2 and NiO. Initial experiments, using the direct-coupled rf power for floating-zone crystallization, yielded polycrystalline rods of NiO up to 5 inches in length. Refinements of technique are currently being made in an effort to produce single crystals.

As a part of the program, an investigation is in progress to develop and evaluate methods of growing highly perfect crystals at temperatures below the melting point of the crystal not only to minimize physical lattice defects resulting from thermal agitation, but also to avoid problems resulting from high vapor pressure, phase transformations, and incongruent melting. This study involves the use of a narrow zone of solvent which is "sandwiched" between a single-crystal seed and the polycrystalline source material. By placing the "sandwich" in a suitable temperature gradient, the polycrystalline material dissolves at the hotter interface, migrates through the solvent, and deposits on the seed. Thus far, a small amount of growth was obtained on a zinc oxide seed crystal using lead molybdate as a solvent.

Single crystals of salts slightly soluble in water are being grown by slow interdiffusion of the component ions in silica-gel medium. The following substances were produced as single crystals up to 1 cm in their longest dimension: copper tartrate, calcium tartrate, calcium sulfate dihydrate, and lead iodine. The diffusion of the reducing agent, hydroxylamine hydrochloride, into silica gel containing copper sulfate forms both fernlike dendrites and dendritic tetrahedra of metallic copper. The substitution of cupric chloride in the same system gives tetrahedral single crystals of cuprous chloride up to 4 mm on edge. The silica gel method seems most applicable to materials having solubilities of the order of 0.01 percent.

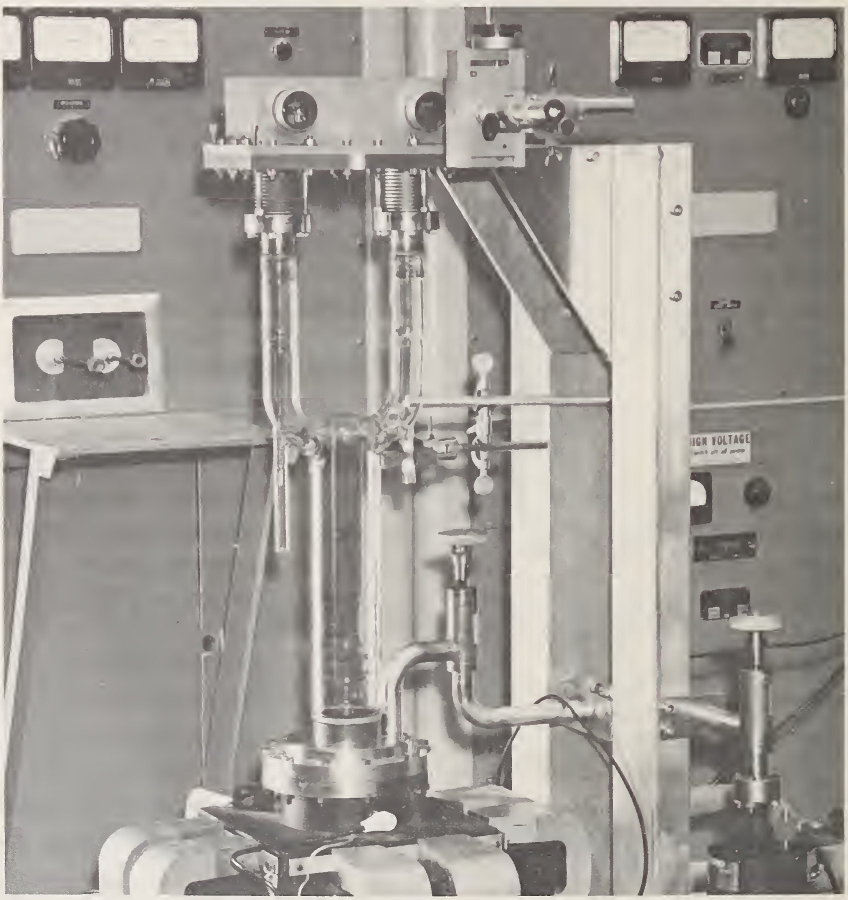
Dislocations in Nonmetallic Crystals Studied. Transmission electron microscopy is being used to reveal dislocations in aluminum oxide, quartz, and other nonmetallic materials for the first time. The relation between etchpits and dislocations, and the interactions between dislocations are being studied. A high-temperature furnace within the electron microscope is used to produce structural changes which are observed directly. The climb of dislocations and the production of point defects by electron bombardment in aluminum oxide were demonstrated. The high-temperature phase transformations of silica are also being studied.

Crystals of High Perfection. The high physical perfection of large single crystals of ammonium dihydrogen phosphate was demonstrated with double crystal rocking curves and x-ray diffraction topographs. The crystals were grown from solutions of reagent-grade material, employing precisely controlled temperature programs. Careful sectioning of the crystals with a string saw, followed by etch-polishing of the surfaces, produced specimens whose diffraction characteristics are believed to approach those inherent in the crystals as grown and are tentatively taken to be representative of the bulk crystal.

A pair of [110] sections give a rocking curve whose full width at half maximum is 2.8 seconds. Rough estimates indicate that this width is comparable to the theoretical value, which implies a neglible "mosaic spread." The general uniformity of the diffraction topograph of these crystals shows the absence of significant strain and indicates regions of 1 cm^2 or more to be free of defect images.

Extensive defect-image patterns appear in the topographs taken on specimens not carefully prepared, on specimens purposely abused, and on single crystals containing appreciable chromic ion impurity. Localized images seen in the topographs are ascribed to emergent and non-emergent dislocations.

Point Defects Studied Using Internal Friction and Dielectric Loss. The effect of point defects (chemical impurities and vacancies) on refractory crystals is under investigation. One method of study is to consider the symmetry of the crystal and to analyze the effects of reductions in this symmetry when the crystal is subjected to mechanical or electrical stress. This approach permits all classes of crystals to be analyzed in a formal way for possible effects of point defects when the crystal is strained.



Determining the rates of vaporization of high-melting-point metals is necessary in the development of thermionic generators of electric power. Here, a microbalance apparatus is used in a very high vacuum to measure the rate of vaporization of tungsten at temperatures to 3000 °C. **(See page 151)**

For instance, in rutile, theory predicts that point defects should cause no internal friction peak if stress is applied in the *c* direction. One peak should occur for isolated defects when specimens are strained in the *a* direction and another peak should occur in this direction for paired defects. Also, one peak, should occur for isolated defects when specimens are strained in the [110] direction; paired defects would not cause a peak in this direction. In rutile specimens doped with Ni or Cr, no peaks occurred for those specimens oriented in the *c* direction, in accordance with theory. With Ni as the dopant, two peaks were found for specimens oriented in the *a* direction and only one peak for specimens oriented in the [110] direction. With Cr as the dopant, only one peak was found in both the *a* and [110] directions. From this, it may be concluded that Ni causes both isolated and paired defects, while Cr causes only isolated defects.

Crystal Structure Determined by X-Ray Diffraction. The study of the crystal structures of boron compounds revealed two new interesting structures in different fields of boron chemistry. The determination of the structures of the isomorphous pair SrB_4O_7 and PbB_4O_7 resulted in a type of boron grouping not previously reported in anhydrous borates. All boron atoms are intetrahedral coordination and the structure contains some oxygen atoms shared by three tetrahedra. This structure and the previously reported BaB_4O_7, where the boron coordination is equally divided into triangular and tetrahedral, show that concepts of predicting the ratio of triangular to tetrahedral boron as a function of composition are not valid.

Another interesting study was the first complete determination of a halogen substituted boron hydride. The structure of iodopentaborane (B_5H_8I) was determined at -25 °C. The iodine is attached to the apex of the pentaborane group, thus confirming nuclear magnetic resonance experiments.

Rate of Vaporization of High-Temperature Materials Investigated. A program for the determination of the rate of vaporization of the high-melting-point metals useful in the development of thermionic generators of electric power is being conducted at the Bureau with the support of the National Aeronautics and Space Administration. A microbalance operating in the very-high-vacuum region which permits measurements at temperatures up to 3000 °C is used in this work.

The rate of vaporization, vapor pressure and heat of sublimation of tungsten, the most refractory of the elements, were determined during the year. The heat of sublimation from the (100) face of single-crystal tungsten was found to be the same as that of the polycrystalline material, within experimental error.

High-Temperature Mass Spectrometry. High-temperature mass spectrometry is being used to investigate the vaporization of solid materials and the chemical reactions of their vapors. In addition to the chemical composition of the vapor species, Bureau scientists are determining their partial pressures and heats of sublimation, the equilibrium constants and heats of their reactions, and the heats of formation of any new vapor species formed.

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A complete study was made of the BeO-BeF_2 system. The ternary gas species Be_2OF_2 was identified and its thermodynamic properties determined. In addition, the heat of sublimation of BeF_2 was measured. A study of the BeO-Al_2O_3 system, still in progress, showed the existence of the ternary gas species BeOAl.

This research is being supported by the Advanced Research Projects Agency under its "Thermodynamics of the Light Elements" program.

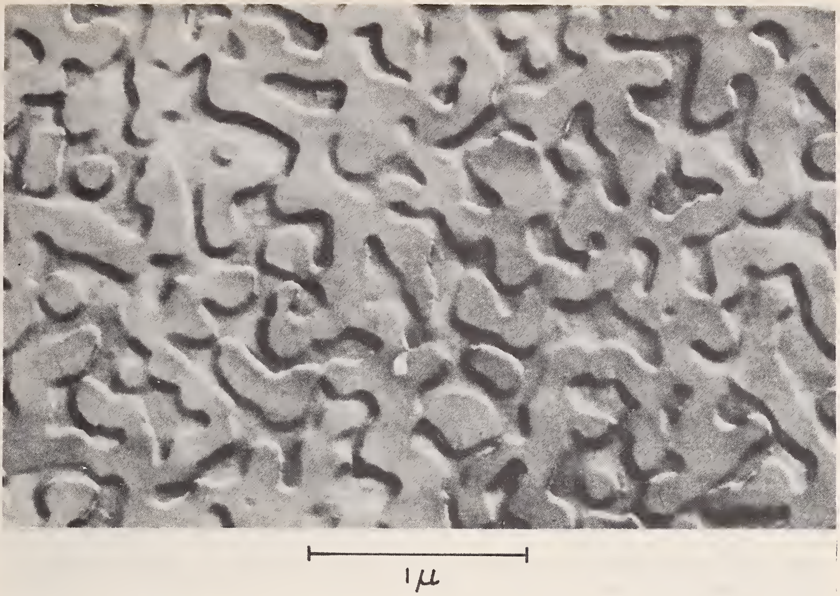
Liquid-Liquid Phase Separation in Inorganic Oxides Studied. The morphology of new phases, which form when a pressure or temperature change is imposed upon a homogeneous system, is generally a function of foreign surfaces which assist the nucleation process. A notable exception is certain liquid-liquid phase separations, which apparently occur without the aid of foreign surfaces resulting in liquid-liquid dispersions of extremely small particle size. These dispersions, by rapidly coalescing into larger units, elude further scientific examination. By choosing a highly viscous system of molten oxides, which could quickly be cooled into glasses, however, it was possible to arrest various stages of the coalescence-process. The two phases are clearly visible, both forming an interconnected three-dimensional network.

Successive stages of the rearrangement process following the liquid-liquid separation were investigated by electron microscopy and by nitrogen adsorption on one of the isolated phases. The kinetics of the process was also determined. A statistical theory explaining the network character of the phases was suggested and various theoretical models for rearrangements by diffusive transport were calculated and compared with the experimental data. The results suggest an interface controlled bulk diffusion process. The process was found to be Arrhenius having an activation energy of 1.67×10^5 joules/mole (40 kcal/mole).

Boron Compounds Studied by Nuclear Resonance. The chemistry of substituted derivatives of the lower boron hydrides was investigated as part of a program dealing with synthesis, properties, and reactions of inorganic compounds. The first known example of a partially fluorinated boron hydride species, difluoroborane (HBF_2), was prepared and characterized. Synthesis of this compound indicates that derivatives of this type may not be as inherently unstable as was supposed. Chemical and spectroscopic properties of the new compound were studied to provide a better understanding of the effect of substitution on the reactivity of boron hydride derivatives.

Measurements of high-resolution nuclear magnetic resonance (NMR) spectra at low temperature were carried out for a number of boron compounds. These studies provide information about the structures of these compounds and may lead to a better understanding of the chemical bonding in them.

Viscosity of Glasses Measured. A high-temperature rotating-cylinder viscometer was modified so that the viscosity of molten glasses can be measured over the range 10^1 to 10^{10} poise. The method, based on room temperature calibration with standard viscosity oils, involves three different



Sodium borosilicate glass, heated below immiscibility temperature, separates into two immiscible glassy phases. Electron micrograph shows preshadowed carbon-replicas of fracture surface. **(See page 152)**

techniques in measuring the torque on the inner cylinder. Over the range 10^1 to 10^5 poise, the outer cylinder is rotated at a constant speed and the torque is measured on the inner cylinder with an electromagnetic torque head by a null balance method. Over the range $10^{4.5}$ to $10^{7.5}$ poise, an aperiodic method is used, wherein the inner cylinder is rotated through an angle and time as it decays to its zero position. Finally, over the range of $10^{6.5}$ to 10^{10} poise the inner cylinder is driven and timed through a specified angle by means of the electromagnetic torque head. These techniques overlap each other so that a continuous viscosity curve can be established for the glass. With these new determinations the results of viscosity measurements by the fiber elongation method on Standard Glass No. 710 were verified in the range of 10^8 to 10^{10} poise. Furthermore, precise viscosity measurements in the range of 10^6 to 10^8 poise can now be made on many glasses where none were possible before. This method also lends itself to viscosity measurements on glasses that cannot be drawn into rods (such as dehydrated B_2O_3 glass) and measured by the fiber elongation method.

Mechanical Properties of Glass Studied at Elevated Temperatures. Increased use of glass at elevated temperatures indicates a need of reliable information, not previously available, on the strength of glass under these conditions. The effect of temperature on the strength of several commercially available glasses was studied to supply this information.

The results indicated that the strength of glass in relation to temperature was apparently dependent upon composition. The modulus-of-rupture values for annealed glass show that after a short-term exposure to elevated temperatures the glasses with the lower silica content decrease in strength while the glasses with the higher silica content continually increase in strength from room temperature upwards. Heating for long periods of time did not adversely affect the strength of annealed glass, and at the higher temperatures tended to strengthen the glass.

The modulus-of-rupture values obtained for the semi-tempered and tempered specimens gave results as expected: generally, the longer and higher the specimens were heated, the lower were the modulus-of-rupture values.

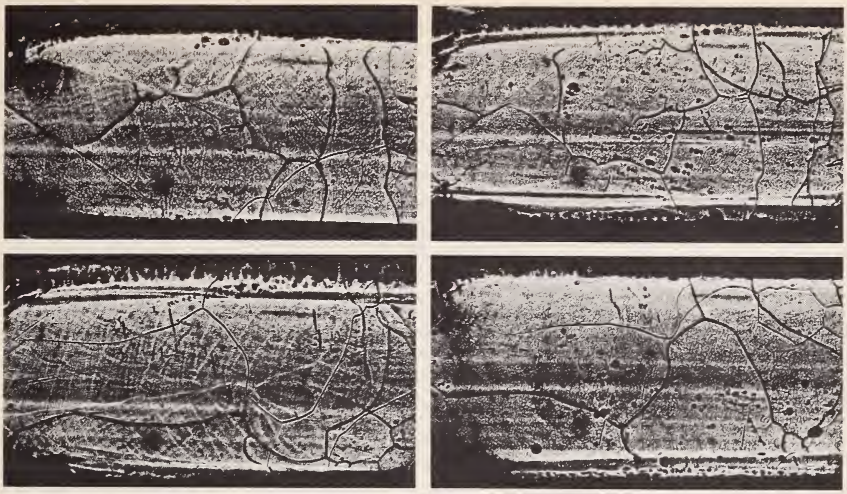
Young's modulus was also affected by temperatures. The same glasses that decrease in strength decrease in Young's modulus, while the glasses that continually increase in strength initially increase in Young's modulus.

Configurational Entropy is a Criterion for Glass Transformation. A new analysis of existing experimental data clarified the understanding of the conditions under which equilibrium supercooled liquids change into glasses. Previous theories suggested that this change occurs when the free volume fraction of a material decreases to some critical value. It is now indicated that an equally determining property is the configurational entropy of the material. This indication comes independently from both molecular relaxation data and calorimetric data for supercooled liquids. The relaxation data may be in the form of viscosity data, dielectric data, dynamic mechanical properties, or creep or stress relaxation data. Both types of evaluation indicate that when the equilibrium supercooled liquid changes into a glass, the configurational entropy has decreased to about 0.8 entropy units per polymeric chain unit. This requires a polymeric interpretation of the molecular structure of the glass forming material. The fact that configurational entropy is now indicated to be a critical property in glass transformation has stimulated re-examination of previous theories and their possible relation to configurational entropy considerations.

Methane Crystals Formed. Experiments on low-temperature crystallization yielded single grains of methane as large as 8 mm × 5 mm × 5 mm in a polycrystalline block. Thermal-etching techniques make possible nondestructive three-dimensional observation of the grains for spectroscopic, solid state, and surface physics studies at low temperatures. Methane is the simplest molecular solid, next to the solidified rare gases, but in contrast to these, undergoes solid-solid phase-transitions. The experiments are aimed at elucidating the nucleation mechanism for such phase changes.

Metal Oxide Melting Point Standards Redetermined. A recent critical compilation showed that the melting points for many of the more common and commercially important oxides are not known with any degree of accuracy or reliability. In order to help rectify this situation, a program was undertaken to redetermine the melting points of selected oxides and to establish calibration standards.

Because many oxides are susceptible to either reduction or oxidation upon heating, it is necessary to study their melting behavior under carefully controlled environmental conditions. An induction furnace was constructed



Four sides of a methane crystal at 87 °K seen through liquid argon. The heavy lines are grain boundaries on the back faces of the crystal and the lighter ones are grain boundaries on the front faces. These crystals provide excellent sources for spectroscopic, solid state, and surface physics studies at low temperatures. **(See page 154)**

which permits the heating of oxide samples to 3000 °C in vacuum or inert atmosphere and to 2400 °C in an oxidizing environment. Either pure tungsten or iridium crucibles serve as both the heating element (susceptor) and as the blackbody for temperature measurement. Considerable attention was given to the design of the susceptor-blackbody in order that a high degree of accuracy of temperature measurement can be achieved. Theoretical calculations as well as experimental testing showed that the blackbody has an effective emittance of 0.999 at 2000 °C. This small deviation fom a perfect radiator, which has an emittance of 1.000, will cause an error in measurement at 2000 °C of less than 0.25 °C.

Because of various influencing factors, only a limited number of oxides are considered suitable for use as melting point standards. At present, the more promising materials include Al_2O_3, Y_2O_3, and Sc_2O_3. The melting point of high-purity single crystals of Al_2O_3 (sapphire) *in vacuo* is now being actively investigated.

Standard X-Ray Powder Diffraction Patterns. NBS, in cooperation with the American Society for Testing and Materials and the American Crystallographic Association, is actively engaged in a continuing program for the further refinement and extension of the use of x-ray powder diffraction patterns as a means of identifying and characterizing crystalline phases. Cooperative work is in progress on the determination of intercomparative intensities to extend the accuracy of quantitative analysis by this method, and in the preparation and measurement of tungsten and silver samples for use as internal calibration standards for spacings. The Bureau initiated a program for the calculation of patterns of materials not readily available or too unstable for experimental study. During the year experimental work was completed on about 60 well-characterized inorganic compounds. Information on the *d*-spacings, relative intensities, cell size, structure type, and density are being published.

Inorganic Materials Studied by Infrared Spectroscopy. Infrared studies of B^{10} and B^{11} substituted-anhydrous borates were carried out in the 2,000 to 300 cm^{-1} range. Spectral bands for all ortho-, pyro- and some meta-borates could be assigned satisfactorily. From correlations between spectra and structure it appears that boron in threefold or in fourfold coordination can be identified on the basis of the infrared spectrum alone. Triangularly coordinated boron is characterized by the presence of strong, broad absorption in the 1,100 to 1,300 cm^{-1} region. In addition, there is absorption in the 700 to 780 cm^{-1} region. Both of these characteristic bands are strongly dependent on isotope mass and thus isotopic substitution can be used to differentiate these bands from others occurring in these regions.

The most characteristic feature of tetrahedrally coordinated boron is the presence of strong, broad absorption in the 800 to 1,100 cm^{-1} region. Also, absorption bands, which are not sensitive to isotope mass and therefore can be distinguished from triangular boron, occur in the 700 to 800 cm^{-1} region.

These studies were used to predict that tetrahedral coordination of boron occurs in SrB_4O_7. This was confirmed by single-crystal x-ray diffraction studies.

2.2.5. REACTOR RADIATIONS

During the past year the Reactor Radiations Division was created from the former Reactor Group. The new division continues with its responsibility for the procurement, operation, and maintenance of the National Bureau of Standards Reactor facility, the NBSR, a high-flux, tank-type, heavy water moderated reactor using enriched fuel. The reactor has an eventual power capacity of 20 megawatts, but will operate initially at 10 megawatts, with an in-pile flux of 10^{14} neutrons per square centimeter per second. It will have 15 beam ports, and will be housed in a building providing 50,000 square feet of usable laboratory space. The reactor is designed to meet the needs of a number of Federal agencies and scientific institutions in the Washington area, and thus has many unique features as a radiation source. Ground was broken and construction started in the past year, with completion scheduled for spring of 1965.

The division has been supervising construction of the reactor with a staff in offices established at the site. Preparations are under way for training operators and generating technical specifications and further hazards analyses in pursuit of an AEC operating license.

The aim of the Reactor Radiations Division is to promote reactor-oriented work of general significance to NBS and of particular significance to the Institute for Materials Research. Staff competencies are being created in three scientific sections in the formative stage. By title, these are the Neutron-

Nuclear Physics, Neutron Solid-State Physics, and Radiation Effects Sections. They will not only generate work of their own, but will also embark with other divisions on cooperative projects of mutual interest.

Flux Standardization. The reactor facilities of the Argonne National Laboratory, the Brookhaven National Laboratory, and the Naval Research Laboratory were utilized to begin several research and development programs. An investigation is being made into the absolute measurement of neutron flux relative to thermal flux standardization. Glass beads containing boron and an element that can be activated, for example, dysprosium, have been made by NBS. These beads are to be activated in a neutron beam at the Graphite Reactor of the Brookhaven National Laboratory. If the neutron current density of the beam is measured by absolute neutron counting, the glass beads can be calibrated for measuring an unknown flux. Boron added to the glass makes a bead that is essentially black to thermal neutrons.

Research and development effort began on a fast neutron spectrometer for reactor spectrum fast neutron flux standardization. The graphite reactor at the Brookhaven National Laboratory is being used as the neutron source. A semiconductor He^3 spectrometer is used for neutron measurements. The system will ultimately assist radiation effects studies at NBS by characterizing the fast flux spectra of the NBSR.

Molecular Motion. The research reactor, CP–5, at Argonne National Laboratory was used by members of the NBS staff to study the molecular motions in solids and liquids. Neutrons with energies of the order of or lower than the energies of the molecular motions to be studied were scattered from the sample, and their energy change was measured by a time-of-flight spectrometer. The measurements provided direct information on the molecular binding in ammonium salts and on the motion of methyl groups in various compounds.

Lattice Vibrations. The lattice vibrations of gray tin (diamond structure) and white tin (tetrahedral structure) were studied using the slow neutron facility at Brookhaven National Laboratory. The energies of the peaks in the phonon spectrum of gray tin are in good agreement with the corresponding peaks in silicon and germanium if the energies are scaled using the square root of the atomic mass. This implies that the interatomic forces are of the same order of magnitude in the diamond structures—silicon, germanium, and gray tin.

Neutron Moderation Study. Preliminary results were obtained in a second experiment at Argonne to measure the ability of various materials to moderate neutrons to subthermal energies. A large volume of heavy water ice (D_2O) about 18 inches in diameter held at 22 °K was shown to be quite effective.

Neutron Optics. A study of the properties of several neutron optical devices was undertaken at the Brookhaven National Laboratory Graphite Research Reactor. These experiments centered mainly on the investigation of the properties of curved totally reflecting pipes and curved totally reflecting soller collimators.

A neutron reflecting pipe in connection with reactor neutrons can be used as a neutron conductor, a background suppressor, and a neutron filter. These properties were studied for both metal and glass pipes coated (electroless) with nickel and installed in a beam hole at the Brookhaven Graphite Reactor.

In addition to their uses as neutron filters and background suppressors, curved totally reflecting soller collimators can be employed as order-removing devices when used in conjunction with a crystal monochromator. An investigation is being conducted on the further use of these soller slits as magnetized cobalt-iron shims to obtain 100 percent polarized cold neutrons.

Establishing Vacua. The establishment of high vacua in the intense radiation field of a reactor core is limited by poor conducting geometry (i.e., systems with a large length-to-diameter ratio), suitable reactor materials (i.e., materials having low neutron absorption), and radiation-induced outgassing. An investigation was made of the magnitude of the radiation-induced outgassing rate of a well-cleaned and baked 6061 aluminum system. Measurements performed in both the NBS 31 kCi cobalt-60 gamma facility and the Naval Research Laboratory's 1 megawatt reactor facility disclosed that the phenomenon of radiation-induced outgassing was principally due to the gamma and its associated electron field, rather than to the fast neutron field. The magnitude of the effect observed was 6×10^{-11} torr liters/sec cm^2 per watt/gram, which can be compared with the field free value for the system of 5×10^{-14} torr liters/sec cm^2.

2.2.6. CRYOGENICS

The Bureau's Cryogenic activities, centered at the Boulder Laboratories, provide data on the bulk properties of materials in the environmental extreme of very low temperatures. Research is conducted at cryogenic temperatures to determine the physical properties of materials, the engineering properties of systems, and to develop methods for measuring these properties. In addition, a national cryogenic data center is maintained where information is collected and organized for use by other Government agencies, industry, and the public.

An addition to the Cryogenics Laboratory Building has just been completed, increasing the space available by nearly 30,000 square feet. Research on properties of cryogenic fluids and measurement methodology, now conducted in two temporary buildings, are being moved to the new addition.

Viscosity of Parahydrogen Determined. The most advanced chemical and nuclear rockets use hydrogen as fuel or as monopropellant. Because of these important applications, the thermodynamic and transport properties of hydrogen need to be known with higher accuracy and over wider ranges of temperature and pressure. The Bureau is engaged in an extensive experimental program to determine these data, a major part of which is supported by the National Aeronautics and Space Administration (NASA). Previously pressure-volume-temperature and thermal properties were determined, and extensive provisional tables of thermodynamic functions were published.

In the past year, measurements of viscosity were concluded covering the same pressure and temperature ranges as the previous work, up to about 3.4×10^7 newtons per square meter (N/m^2) (340 atm) and from 15 to 100 °K, thus including the liquid and gaseous phases and the critical region. The viscosity was determined via the damping of a torsionally oscillating piezoelectric quartz cylinder.

It is conventional to separate the viscosity into a low-pressure component and a remainder, termed the "residual" viscosity. Some published correlations and extrapolations were based on the assumption that the low-pressure component contains the entire effect of temperature on the viscosity, so that the residual viscosity is a pure function of density. The present data show clearly that this is a gross oversimplification. Also, there is no evidence for an anomalous peak at the critical point, as was obtained for some other fluids by other experimental methods.

Solid-Vapor Equilibrium in the Hydrogen-Methane System. Phase equilibrium studies of mixtures are of great practical value in designing fluid purification systems. In addition, provided the components have widely different critical constants, condensed phase-gas equilibria lead to sensitive determination of the parameters for interaction of the unlike molecules.

The hydrogen-methane system was investigated by measuring compositions of gaseous mixtures of hydrogen and methane in equilibrium with solid methane at temperatures from 35 to 87 °K and pressures up to about 1.5×10^7 N/m^2 (150 atm). Enhancement factors and cross virial coefficients were derived. The data will be useful in designing hydrogen gas purifiers. In addition they can be used to evaluate various physical models for the interaction forces between hydrogen and methane molecules.

Mixtures of Solid and Liquid Hydrogen. Space vehicles fueled with hydrogen in liquid form have required the development of new technology. Although relatively high density at low pressures is accomplished by gas liquefaction, problems exist with fluid behavior before, during, and after launch. Some of these problems are (a) short holding or storage time caused by low heat of vaporization and temperature combined with minimal insulation, (b) fluid temperature stratification resulting in pump cavitation problems, (c) sloshing of the liquid in such a manner to effect flight stability, and (d) safety problems associated with the high vent rates before and after launch. Further refrigeration of the liquid to form a "slush" or mixture of solid and liquid should eliminate or greatly reduce a number of these problems.

Under sponsorship of NASA, the Bureau is conducting a program on "slush" hydrogen aimed towards an optimization of the concepts to be incorporated in a space vehicle launch facility. The effort will be carried out on a laboratory scale with emphasis on the applicability to the ultimate large-scale requirement. Specific objectives are to evaluate, correlate and combine all known applicable properties of slush hydrogen, to investigate production methods, and to study flow characteristics. Instrumentation of the three-phase (single-component) system is a crucial portion of the program. A study of the behavior of solid hydrogen crystals in the solid-liquid mixture is also of great importance. The attainment of these objectives will assist in the establishment of standard specifications for instrumentation and production of flowable mixtures of solid and liquid hydrogen.

Superconductivity. The Atomic Energy Commission (AEC) is supporting Bureau work on thin film and high field superconductors. In thin film experiments, careful sample alinement resulted in much better agreement with the Ginsburg-Landau theory than previous workers reported. This supports the use of the theory, which rests on not too firm ground, in high field superconducting problems. A parallel experiment to test another prediction of the theory on bulk superconducting niobium is well under way. Finally, experiments are under way to deduce the topology of the Fermi surface of niobium from magnetoresistance measurements, and to relate this as far as possible to the Class II superconducting behavior of this element.

Metallurgy. Investigation showed that small changes in the elastic moduli observed in certain 300-series stainless steels are related to antiferromagnetic transitions in these metals at about 40 °K. Based on this research, consultation was given to interested groups in NASA and the Air Force who are concerned about possible structural failures due to martensitic phase transformations in stainless steels subject to high stresses at liquid hydrogen temperatures.

Electronic Properties of Copper Investigated. Magnetoresistance measurements indicate that the simple concept of a (scaler) electron mean free path in copper, and presumably in other metals, must be abandoned in favor of more sophisticated analyses involving details of the electronic structure.

The theoretical implications of this advance are being investigated, and related experimental work is beginning.

Aluminum Cryogenic Magnet Tested. The AEC is supporting an investigation into the feasibility of generating strong magnetic fields at low cost by using liquid hydrogen cooling of aluminum electromagnet windings. Such a magnet was tested to burnout at 9.4 tesla (94,000 gauss). It was found that the cryogenic part of the system (heat transfer ratio, fluid flows, pressures, temperatures, and pumps) performed in accordance with engineering expectations. Additional measurements are necessary in order to be able to predict accurately the resistivity of the aluminum under stress at high fields and at the operating temperature.

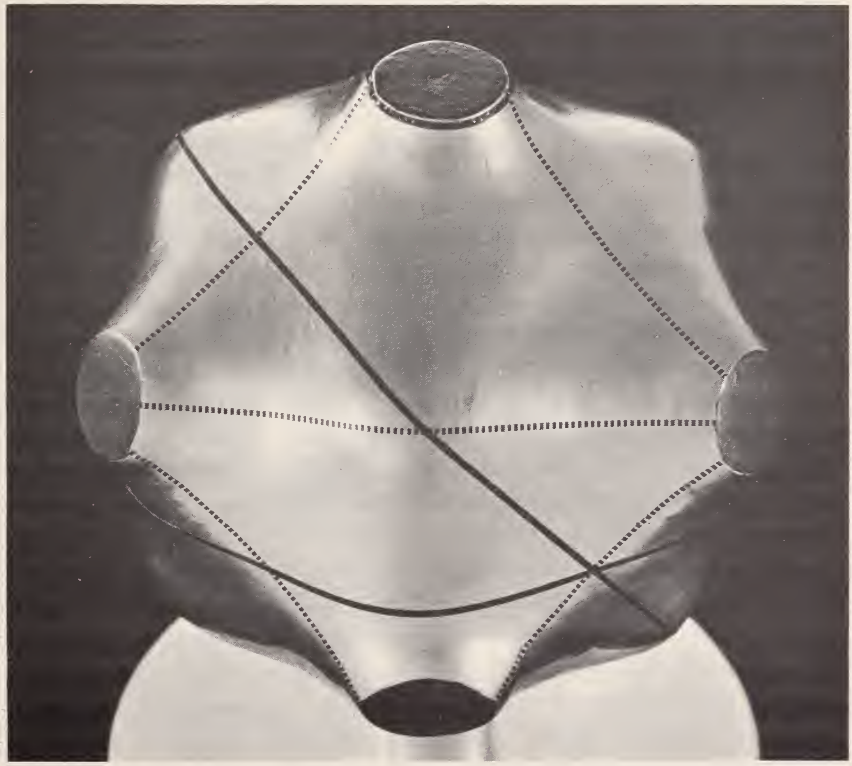
Thermophysical Properties of Cryogenic Materials. With support from NASA and the National Standard Reference Data System, the Cryogenic Data Center is critically evaluating and compiling data on the thermophysical properties of materials from the scientific literature. The objective is to publish authoritative and comprehensive tables and graphs of data in a form convenient to scientists and engineers studying cryogenic phenomena and designing cryogenic systems. If the necessary data to complete a table are not available from the literature, values are computed from correlations based on theory and the properties of related materials.

Extensive tables of the thermodynamic data for carbon monoxide were completed together with a temperature-entropy diagram and a compressibility factor diagram. A compilation of the dielectric constants of cryogenic fluids and an extensive bibliography of the thermophysical properties of argon were also completed.

Temperature-entropy diagrams for helium and neon, and an enthalpy-entropy diagram for helium were constructed and are now available. Also available are interim reports with preliminary thermodynamic data tables for oxygen and argon. Further evaluation of these materials is in progress.

In other work, a bibliography on the saturation properties (vapor pressure, saturation densities, latent heat, and specific heats at constant saturation) of cryogenic fluids was compiled and is in the process of publication. In addition, a collection of thermodynamic data for hydrogen in its various phases and ortho-para modifications is being developed.

Cryogenic Literature Service. The Cryogenic Data Center's documentation unit searches the world literature for technical information per-



Fermi surfaces of copper viewed along the (100) direction. The lines depict various electron orbits of importance in theoretical calculations.

(See page 160)

tinent to the cryogenic engineering field and promotes an awareness of such literature to the Bureau staff and the cryogenic industry. Over 6,000 references were noted and coded for entering into the Center's storage and retrieval system. Additional mechanization (digital computer programming) to reduce the number of manual operations was accomplished, thus reducing unit costs and providing more capacity with existing facilities.

More than 3,300 documents, of which about 1,300 are in microfilm, were procured from world sources for the Bureau staff. The staff distributed an estimated 18,000 items of NBS literature in response to some 1,900 requests. Periodic announcements of available material and services were sent to approximately 4,000 persons and institutions on the Center's mailing list.

A weekly current awareness service was started in March in which about 100 new articles of interest to the Cryogenic field noted during the week were listed and distributed to the Bureau staff. An expansion and improvement in the service is planned with the intent to make it more available to the public.

The documentation unit works closely with the Center's evaluation unit in providing both literature-procurement services and bibliography retrieval. The evaluation unit is not only a primary user of these services, but is also a major contributor of information on cryogenic literature from their compilation programs and the associated literature searching on selected topics.

Measurement Methodology. Typical projects include investigating new thermometric materials; devising simpler calibration-correlation methods; and the modeling of transducer characteristics on analog and digital computers. Research is performed upon those properties of materials, matter-matter and matter-energy interaction, which may lead to new or improved measurement coefficients. Current examples include the study of nuclear magnetic resonance techniques which may be applied to measure the density or velocity of cryogenic fluids; pyroelectric phenomena for measuring small temperature differences; and the piezoresistivity of commercial carbon composition resistors which may be used to measure pressure.

An especially challenging task during the past year was the investigation of transducers for use in the extreme synergistic environment of combined nuclear radiation and low temperatures. In this case, transducers must operate from 20 to several thousand degrees Kelvin in a radiation field unmatched by any existing test reactor.

Continuing programs include investigating means of measuring the density of flowing cryogens, studying the properties of semiconductors at low temperatures, analyzing the temperature dependence of pressure sensors, and determining the fraction solids in a mixture of liquid and solid hydrogen.

Fluid Flow and Heat Transfer. A study was completed on the pool boiling of cryogenic fluids. This study compiled the experimental data available and compared these data with correlations derived for fluids at higher temperatures. The more promising correlations were indicated and graphical solutions using these correlations were presented. This will provide designers of a wide range of cryogenic systems with much-needed boiling heat transfer data.

An analytical method was developed which will predict peak surge pressures which are experienced when a cryogenic fluid is introduced into an ambient-temperature transfer line. It was determined experimentally that these pressures may be several times the initial driving pressure for the fluid. Therefore, this information is very necessary to ensure safe design for cryogenic systems.

In many cryogenic systems, a conduit (tube, pipe) containing a cryogenic fluid is exposed to a gas mixture (usually air) containing water vapor. In order to properly design such a system, one needs predictive expressions to determine data such as the heat transfer rates to the gas mixture and the rates of the frost formation on the conduit. An extensive experimental program was carried out to determine these data and an analysis was completed using a modification of rather conventional heat and mass transfer analogies which shows reasonably good agreement with the experimental data.

2.3. INSTITUTE FOR APPLIED TECHNOLOGY

The nation is currently faced with new demands to put technology to economic use—to create new markets, to compete with foreign industry, to apply technology to our public problems, create jobs, and put our technical resources to maximum use as well as to cope effectively with the social consequences of technical change.

Attention is also being called to certain gnawing social problems which exceed in scope any one industry, company, or region of the country. These include:

—the control of air, land, and water pollution.

—the inadequacy of our systems of land transportation (particularly in urban areas) and the unsolved problems of our nationwide transportation system.

—the inadequacy of our low- and middle-income housing.

—the well-advertised pockets of poverty in the midst of plenty.

—the problem, for much of the population, of adjusting to the constructive use of large quantities of leisure time.

The National Bureau of Standards' concern with these problem areas, in ways appropriate to its resources and its traditions, is reflected in the programs of the Institute for Applied Technology. This consists of four principal activities:

—the dissemination of technical information.

—the development of performance criteria.

—the development of tools for the analysis of large-scale problems that cut across Government-industry lines.

—analysis of problems associated with the introduction of new technology.

The Dissemination of Technical Information

The Federal Council for Science and Technology has established within the Department of Commerce, building on the Office of Technical Services, in the Institute for Applied Technology, a Clearinghouse for Federal Scientific and Technical Information. Its scope includes the physical sciences, engineering, and related technology and it is meant to serve as a central point of contact in Government for industry and the technical community (paralleling the Library of Agriculture and the Library of Medicine, in their fields). Its specific responsibilities are listed on page 167.

The Development of Performance Criteria

The National Bureau of Standards has a historical role in the development of standards for industrial products as well as standards of measurement for physical quantities. There are few standards, mostly concerned with safety and assigned by law in the public interest to the Department of Commerce for which the Bureau has a responsibility to develop and promulgate the standard itself. It cooperates fully with the private standards-producing bodies—industrial associations and professional societies, and groups such as ASTM and ASA. Its role here is to serve as a technical resource to these private groups. It is available for expert and objective contribution to the development of methods of test, measurement, and criteria for the performance of industrial materials, products and processes which lay the technical basis for industrial standards.

The Institute will engage in the development of performance criteria in the fields of building, electronics, textiles, and information processing, among others. In all these areas, it will identify projects of high priority through industry's concern with the problem, as expressed in trade associations, professional societies, and private standards bodies.

The Development of Tools for Analysis of Large-Scale Problems

Many of our most serious technical and technical/economic problems are so large as to cut across industry boundaries: they cannot be located wholly in one industry or wholly in another. Many of these, in turn, cut across boundaries between industry and the Federal Government; both share a concern with them. Examples are to be found in:

—urban and national transportation.

—low-cost housing, for the military as well as for civilians.

—man-machine systems for receiving, sorting, processing, storing, and displaying data.

In these cases, many industries join in production and service, and Government figures as user and purchaser as well as, on occasion, regulátor.

Because of the scope of these problems, as well as the fragmentation of some of the industries concerned with them, they are seldom considered as whole systems even though in many instances they are most effectively considered in that way. Often, the very tools needed to treat them as systems are missing. The Bureau has traditionally provided consultation to Government in its systems problems and in its use of new technology. Frequently in the past—as in the case of the early computer, SEAC—it has developed tools for systems problems of interest to Government and industry alike. The Institute for Applied Technology will continue to fill these functions, in a few areas of special competence.

The Analysis of Problems Associated with Introduction of New Technology

The Institute's major objective—that of stimulating the application of science and technology to national needs—requires an understanding of the problems and obstacles that keep science and technology from being applied to needs, and of the sort of activity that would stimulate their application. This means more concretely:

—analysis of major problems of technical innovation, in industry and Government alike.

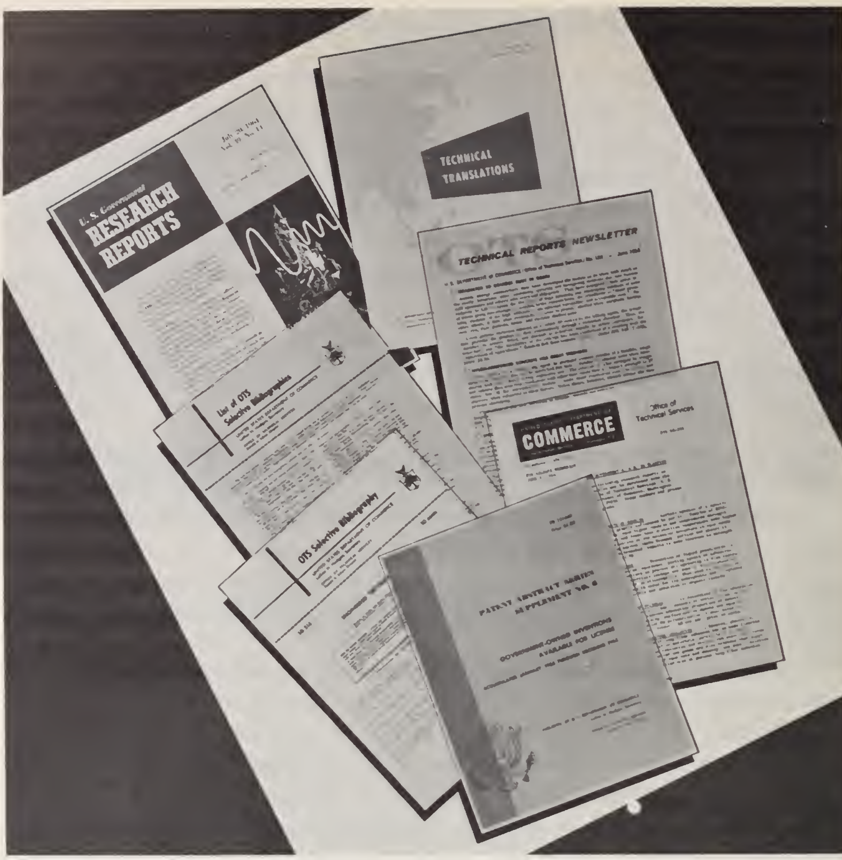
—analysis of the likely effects on new technology of programs currently undertaken or planned within the Institute; e.g., in the areas of performance by criteria, technical information, or systems analysis.

2.3.1. CLEARINGHOUSE FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION

The program of the Office of Technical Services (OTS), established under Public Law 776 (81st Congress) for the collection and distribution of Government research and development reports and translations of foreign technical literature, was strengthened and broadened during fiscal year 1964.

On January 30, 1964, concurrent with the reorganization of NBS, control of OTS was transferred from the Office of the Secretary of Commerce to the Bureau. Shortly thereafter, an interagency agreement under the auspices of the Federal Council for Science and Technology, which was announced by the White House on February 28, 1964, established within OTS the Clearinghouse for Federal Scientific and Technical Information. The White House announcement stated that the Clearinghouse will: (1) serve as the Federal agency through which unclassified and unlimited technical reports and translations will be uniformly indexed and made available to the public; (2) provide current awareness information concerning Government-sponsored research and development; (3) refer to appropriate specialized information centers requests for explicit scientific and engineering information; (4) establish links with the Smithsonian's Science Information Exchange and the National Referral Center for Science and Technology at the Library of Congress.

Another significant development was the signing, on March 9, 1964, of an agreement between the Department of Defense and the Department of Commerce which provided that OTS will handle all processing and distribution of unclassified and unlimited DOD reports, a function formerly performed by the Defense Documentation Center (DDC) of the Defense Supply Agency. The Clearinghouse began the complete processing of unclassified and unlimited to DOD reports in May for publication in DDC's *Technical Abstract Bulletin* (TAB) and for distribution to authorized DOD requesters. These same DOD reports appear in the *U.S. Government Re-*



Typical examples of the various methods used by the Clearinghouse for Federal Scientific and Technical Information (formerly OTS) to disseminate information throughout industry and the technical community. Over 30,000 technical reports and foreign translations were processed into the Clearinghouse collection last year. **(See page 167)**

search Reports (USGRR), a Clearinghouse publication, for distribution to the public domain. Prior to this agreement, OTS had been responsible for the announcement, reproduction, and sale of these documents to the general public only. Processing of the documents by one agency serves all interested user communities and is designed to reduce the cost of such services.

The purpose of the Clearinghouse is to make the results of science and technology more readily available to industry, commerce, and the general public and to reduce duplication and waste in Government technical information programs. The Clearinghouse services are designed to aid Government and industry to increase technological progress and to reduce duplication in research and development.

During the last quarter of fiscal year 1964, an integrated systems design of the total Clearinghouse operation was developed to provide for efficient and reliable service as the workloads expand to higher levels. Shorter processing cycles, earlier announcement, and rapid request service are the goals of this effort.

Document Input Processing. The Clearinghouse receives technical reports, bibliographic information, and translations of foreign technical literature. These are derived primarily from the Atomic Energy Commission; Department of Commerce; Department of Defense; Federal Aviation Agency; Department of Health, Education, and Welfare; Department of Interior; National Aeronautics and Space Administration; and other Federal agencies. A total of 30,000 titles was processed into the Clearinghouse collection during fiscal year 1964. This rate is expected to double in fiscal 1965.

The Clearinghouse accepts from all Departments of the Government, and from those non-Government agencies willing to participate, documents, magnetic tapes, punched cards, abstracts, catalog cards, and other bibliographic records concerning federally sponsored research and development.

Cataloging is the instrument designed to facilitate the announcement and location of materials collected by the Clearinghouse. After the material is processed through descriptive cataloging and abstracting, it is prepared for announcement in journals, either in *U.S. Government Research Reports* or, in the case of foreign translations, in *Technical Translations*. These journals are semi-monthly publications available by subscription from the Clearinghouse. The Clearinghouse also announces Government-owned patents to the technical and industrial community through its Patent Abstract Series.

Document and Information Request Processing. A primary responsibility of the Clearinghouse is to provide its users with pertinent technological information on its vast collection of reports and translations. Use is made not only of the Clearinghouse catalogs, but also of the facilities of other Government agencies. Information is supplied in the form of bibliographies, answers to specific reference questions, identifications of documents, or referral to other proper sources. Requests for information may be made by letter, telephone, teletype, or personal visit. Selective bibliographies are prepared regularly on subjects of general interest. Fee literature searches and subject searches are provided for research organizations, industrial firms, Government agencies, and others.

In addition, the Clearinghouse has initiated plans for:

—Central bibliographic control for Government-generated reports and closely allied literature in the public domain.

—Generation of a Government-wide index to this literature including access by subject, author, source, and number.

—Repackaging of agency abstracts, indexes, and other bibliographic records in special consumer groups, e.g., textiles, machine tools, etc.

—An expanded referral service.

A new standard pricing schedule for the sale of reproduced copies of documents, whether printed by the offset reproduction method or produced from microform, was developed in fiscal year 1964 for implementation during fiscal year 1965. Plans are also under way that provide for subscription to an automatic distribution within selected subject categories. Clearinghouse sales include all forms of publications and bibliographic records such as reports, translations, monographs, directories, reviews, indexes, bibliographies, announcements, journals, abstracts, and catalog cards. The Clearinghouse cooperates closely with existing agency sales mechanisms to avoid unnecessary duplication of effort. For documents, both reproduced copies and microform are available. Distribution of shelf stock is accomplished within 24 hours of the receipt of requests; if reproduction is required, an additional 3 days maximum is necessary. This service is designed to provide the fastest practical response to user requests.

In its translations program, the Clearinghouse provided central directories and Clearinghouse services for technical translations of scientific and technical literature in the Slavic, Oriental, and other unfamiliar languages. It produces a semi-monthly listing and index (*Technical Translations*) to all translations made in the United States and abroad in English and in Western languages.

2.3.2. WEIGHTS AND MEASURES

The control of weights and measures in the United States presents a unique situation in the governmental structure of this country because regulatory control has historically remained with the States, counties, and cities, even though fixing the standards of weights and measures is specified in the Constitution as a Congressional authority.

Such local control results in an obvious advantage—it allows problem solutions to be patterned to local conditions. A disadvantage, however, is equally obvious—the possibility of more than 50 different systems of weights and measures. To avoid this possibility, the Department of Commerce—and through it, the National Bureau of Standards—has been charged by the Congress with the custody, maintenance, and development of the national standards of measurement, and with the provision of means and methods for making measurements consistent with those standards. To assist the State weights and measures programs, the Bureau tests and calibrates State standards and standard measuring apparatus and provides technical advisory services. To assure uniformity in weights and measures laws and in methods of inspection, the Bureau extends general cooperation to State weights and measures officials.

Thus the Bureau maintains an Office of Weights and Measures, which is responsible for (1) technical assistance to the States and to business and industry in the area of measurements; (2) the design, construction, and use of weights and measures standards and of instruments associated with such standards; (3) the training of weights and measures officials in the technical aspects of their program; (4) technical assistance in the solution of special measurement problems; (5) developing model laws and regulations; (6) arranging national, State, and regional conferences; and (7) the collection, arrangement, and dissemination of technical data on measurement units and systems.

Technical Services. At the request of the legislature of the State of Mississippi, the only State that still had no comprehensive weights and measures law, an intensive survey of weights and measures conditions was conducted in that State. Seven representative cities were visited where tests of devices were conducted, test measurements of packaged commodities were made, and general weights and measures conditions were observed. The conditions revealed by the survey led directly, in March 1964, to the enactment by Mississippi of the National Conference on Weights and Measures Model State Weights and Measures Law.

Studies of rental car and truck odometer accuracy continued through the year. In cooperation with representatives of the automobile industry, detailed test procedures were developed, a single vehicle test speed and tire pressure were recommended, and tolerances were studied and revised. As a result of NBS efforts in this area, odometers on all cars furnished to rental fleets now comply with newly established tolerances and, eventually, all cars manufactured in the United States will more accurately register distance traveled.

The increasing production of packaged aerosol products has brought about a concomitant need for accurate net content testing methods. Accordingly, research has begun to determine test procedures that will be both usable by weights and measures officials and workable for industry. The great variability in products packaged in aerosol containers presents a unique problem of categorizing. This was solved by the establishment of five categories on the basis of product characteristics. Testing within the first category, foam

Weighing aerosol cans during a research program to establish effective test procedures for determining net content of aerosol products. **(See page 171)**

products (shaving cream, shampoos, etc.), was completed during the year, and definite procedures were prepared in draft form for review by industry and State officials.

Standards. As part of the Latin American standards program, translations of U.S. weights and measures publications into Spanish and Portuguese were completed. New State standard designs were revised to metric denominations for use as national standards; a complete set of mass, length, and capacity standards were procured; and plans are being considered by the Department of State to display these in Latin America (see p. 24).

Technical Training. Formal training schools were conducted in 11 States and field training on specific devices or package-checking methods was provided in several others.

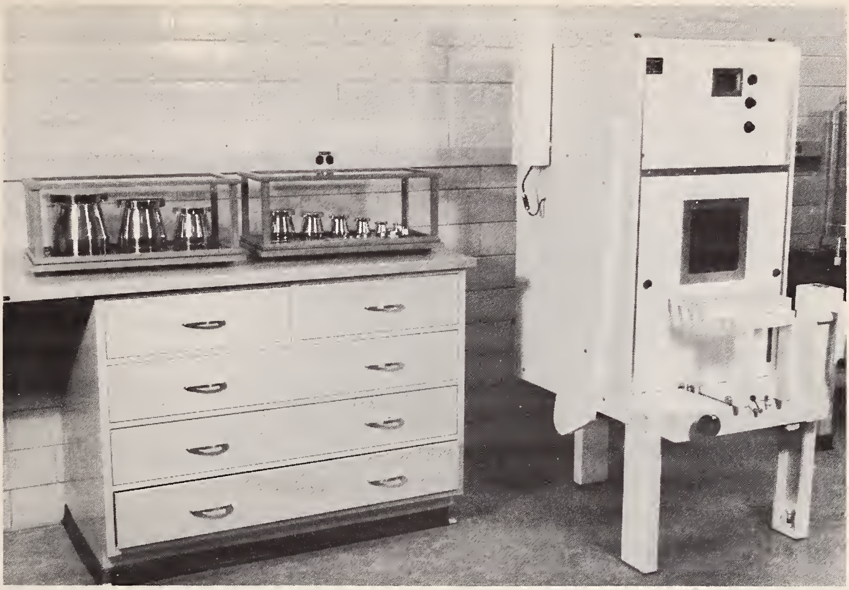
In an effort to make technical training more easily available to a greater number of weights and measures officials, a packaged series of audio-visual self-training aids was devised. The first, on computing scales, is now available and the script for a second has been written.

With the assistance of the Office of Weights and Measures and of weights and measures equipment manufacturers, a significant new educational program was established at the Alfred State University of New York. The new Measurement Science curriculum is an attempt to answer at least partially the need for a college-level training course for weights and measures technicians.

Technical Information. Publications issued during the year include Misc. Publ. 247, *Weights and Measures Standards of the United States;* Tech. Note 195, *Report on Technical Investigation of Odometers;* Tech. Note 196, *Report of the Investigation of Slow-Flow Meters for Fuel Oil Distribution Systems;* Handbook 98, *Examination of Farm Milk Tanks;* and several articles in technical periodicals. Handbook 98 is the first of a series of pocket-size handbooks that, in total, will succeed Handbook 45, *Testing of Measuring Equipment.*

National Conference. The 49th National Conference on Weights and Measures held during the year broke all previous attendance records. Forty-one States, the District of Columbia, Puerto Rico, Canada, and England were officially represented among a registered attendance of 633. A significant accomplishment was the establishment by the Conference of package quantity declaration standards. Consumer affairs received emphasis in the papers presented. Other papers dealt with technical measurement matters, and such subjects as weights and measures activities of other agencies of the Federal Governmnt, and the reorganization of the National Bureau of Standards.

Federal-State Technical Services. During the year, an entirely new program was established to assist the States in solving local and regional industrial problems. As a part of this program, a National Conference on State Science and Technology and similar regional conferences will be organized.



As part of the Latin-American Standards Program, a new set of mass standards, converted to metric units, has been designed and built. The set ranges from 30 kilograms down to one milligram. At right is a 30 kilogram precision one-arm balance, also developed for this program. **(See page 172)**

2.3.3. ENGINEERING STANDARDS

An Office of Engineering Standards was established in recognition of the basic importance of standards to the entire area of applied technology. The new Office brings together at NBS present activities of the Department of Commerce on commodity standards, technical standards coordination, and international standards. The Office has also been assigned the responsibility for developing specifications for seat belts for use in motor vehicles. As soon as these specifications are available, they will be promulgated by the Secretary of Commerce.

Commodity Standards. Technological information available at NBS finds direct application in commodity standards for improving production and marketing practices, and for enabling consumers to obtain products of recognized standard types, sizes, grades, and qualities. The Office of Commodity Standards cooperates with industries requesting assistance on standards for their manufactured products . Two types of commodity standards are published: "Commercial Standards" and "Simplified Practice Recommendations." For a list of both types made available in fiscal year 1964, see p. 254.

Commercial Standards give technical requirements for materials, construction, dimensions, tolerances, testing, grading, marking, or other details. The objectives are to define quality levels for products in accordance with the principal demands of the trade and to provide for close adherence to the qualities thus defined. Uniform methods and practices are established for achieving and determining compliance.

Simplified Practice Recommendations are essentially lists of stock or staple items in greatest demand. They make possible a choice, in accordance with generally recognized trade practices, between "standard" items that are widely available from distributors' stocks, and "specials," which may require factory orders and more costly production and handling methods. Some recommendations give standard methods, such as methods of packaging.

The commodity standards activity began at NBS in 1921 as a program of aid to business for general economic improvement. Transferred to another part of the Department in 1950 and returned to NBS in 1963, the present program embodies the experience of 43 years of close cooperation with technical organizations, trade groups, purchasers, consumers, and producers on standards for more than 500 widely used manufactured products. The method by which the standards are developed emphasizes their voluntary adoption by all of the above elements of the industry. The list of acceptors is published in the standard to show the extent of public support for it. In addition, most standards include recommendations for certification and labeling to enable purchasers to identify the products that meet the standard. Some industry groups employ commercial inspection and testing programs, together with grade labeling, hallmarks, or certificates, for greater effectiveness in making their products more acceptable to consumers, through conformity to a commodity standard.

Technical Standards Coordination. The Office of Technical Standards Coordination is responsible for coordinating the development and revision of Federal Specifications work at NBS, serving as liaison between NBS and other Government agencies engaged in standardization work, and in providing information and copies of specifications to NBS and outside sources upon request. During the past year, 550 proposed Federal Specifications were reviewed by NBS personnel and comments transmitted to the appropriate Government agencies. The specifications were reviewed to determine technical accuracy and suitability for use by the Federal Government.

The Bureau accepted responsibility for preparing and maintaining one additional Federal Specification, making a total of 153 for which it now has this responsibility. Complete files of over 4,000 Federal Specifications and Standards were maintained as well as files of British and German Standards and selected industry standards. Requests for information and specifications were received from NBS and Harry Diamond Laboratories personnel, Government agencies including members of Congress, embassies and foreign countries, and the public. These requests covered such subjects as Government, domestic, and foreign standardization, and problems of cross-referencing standards of various countries.

The Bureau's interest in engineering standards and test methods was evidenced by the 1,400 committeeships held by NBS staff in 156 national groups such as the American Society for Testing and Materials, the American

Standards Association, and the American Society of Mechanical Engineers. Records for these activities as well as special committee reports to the Secretary of Commerce were maintained.

Standards for Developing Countries. NBS is concerned with two types of standards for developing countries: (1) standards of weights and measures; and (2) standard practices, including codes, specifications, and methods of testing. Both categories of standards are essential for commerce and trade and indispensable for industrial development.

During the year the Bureau procured (with funds from the Agency for International Development) a set of standards of mass, length, and volume specially designed to serve as the national standards of developing countries. These standards and the accessory instruments for their use combine a high degree of accuracy and permanence with unusually rugged construction and practical utility. This equipment will be placed in a Latin American university where it will serve both as standards of measurement for the host country and for demonstration and training purposes for other countries (see p. 24).

In the field of standard practices a number of standards that are widely used in the United States were translated into Portuguese and Spanish, also with the support of the Agency for International Development. These included safety standards which were translated by contracts in Latin America let by the Bureau of Labor Standards, and specifications, methods of test, and manuals that were translated in cooperation with the University of Miami.

As in previous years the Bureau cooperated with the American Standards Association in providing technical experts to serve on United States delegations to international meetings on standards. Noteworthy progress was made in a number of areas of standardization, particularly in the development of Pan American Standards for textiles, iron and steel, steel products such as pipe and tube, cement, and concrete.

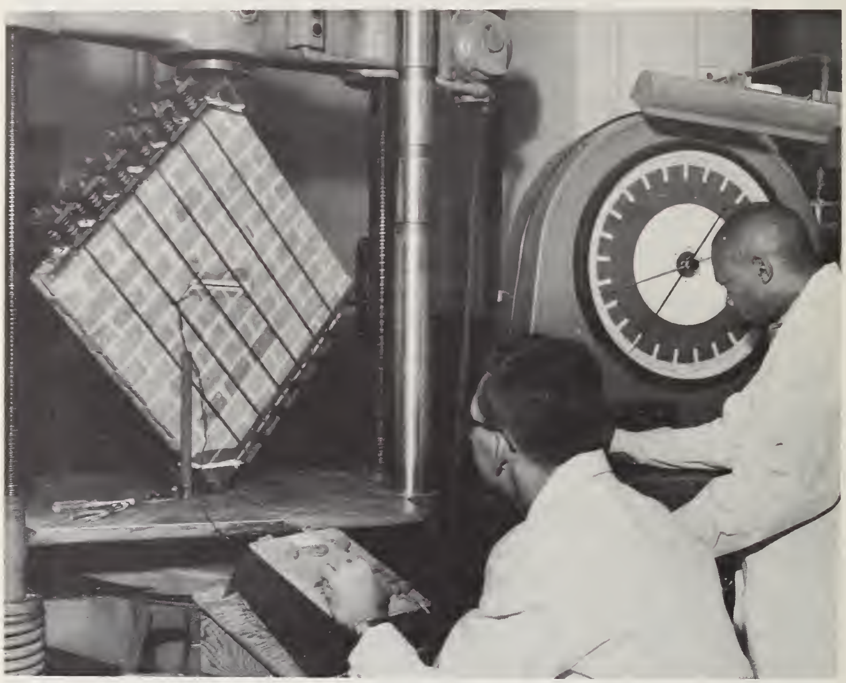
2.3.4. BUILDING RESEARCH

The diversity of problems in the field of building materials, construction, and systems is such that research is required in physics, chemistry, and many of the subdisciplines of engineering. These researches provide both data on the performance characteristics of buildings and their components; and test methods for measuring these characteristics. The studies range from basic research to applications of the Bureau's competence to specific building problems. The development of test methods and laboratory reference materials is often carried out in cooperation with interested laboratories of industry, educational institutions, and other Government agencies. The information developed is made available to the building industry and code-writing groups as an aid to increased effectiveness in the use of building materials and equipment.

An important service is that of consultation and advice to other Government agencies on building problems, and to other organizations in the formulation of standards of value to the building industry. For example, advice and assistance were furnished the Federal Aviation Agency in connection with studies they have conducted on the flammability of interior-finish materials for aircraft. Technical assistance was also provided to the U.S. Army Corps of Engineers regarding the selection of siding material to be used to enclose the Vertical Assembly Building for the Saturn rocket at Cape Kennedy, Fla.

A member of the staff spent 3½ weeks in South America, as the official American Standards Association representative, participating in the preparation of Pan American Standards for portland cement. In addition, meetings were held with standards organizations, universities, and cement manufacturers in Brazil, Uruguay, and Argentina.

Strength of Prestressed Concrete Beams Investigated. Prestressed concrete owes its remarkable properties to the fact that precompression in the concrete created by means of tensioned reinforcement counteracts tensile stresses which are developed in the structure under load. NBS is studying the properties of a new system, dubbed "split-beam" by its originator at the Bureau of Yards and Docks. This system consists of a prestressed portion of a beam in which tensile stresses are expected to develop under service loads, and a subsequently cast nonprestressed portion in which only com-



Scale model (¼ actual size) of masonry block wall subjected to racking test. Spring-loaded yokes simulate the normal vertical load on the wall. This method greatly simplifies the previous standard test procedure and applies forces more nearly representative of the system encountered under service conditions.

(See page 177)

pressive stresses are expected to develop under load. The two portions are bonded and become a monolithic beam. As the prestressing in the "split-beam" system is confined to only a portion of the beam, a smaller tensioning force is required, and considerable economies in the amount of steel can be effected.

The investigation at the Bureau was intended to determine how the two-stage casting of the "split-beam" members affects their properties. The results indicated that the resistance to flexure and shear of prestressed concrete was not affected adversely by the "split-beam" method of construction.

Masonry Racking Test Simplified. The present standard racking test for masonry consists of applying a horizontal force in the plane of and at one top corner of a wall, while it is prevented from sliding by a suitable stop at the bottom, and from overturning. The test requires a massive self-contained loading frame sufficiently rigid to resist the system of forces involved in the test.

In an effort to simplify the test procedure and to apply forces more nearly representative of the system encountered under service conditions, a test procedure was developed in which the racking load was applied with a suitable compressive testing machine, while a system of spring-loaded yokes simulated normal vertical load along the top edge of the wall. The test procedure was developed using quarter-scale models of concrete masonry units. By selecting proper proportions of mortar and suitable conditioning of the masonry units before and after fabrication of the wall models, racking failures were obtained which were quite similar to those observed in prototypes. It was found that application of relatively small boundary forces had a measurable effect on the racking strength of the models of masonry.

Models Used in Fire Research. In spite of the extensive qualitative knowledge gained on the behavior of fires in buildings, it is highly desirable to achieve a more exact understanding of the effects of different variables on such fires. The high cost, in both time and money, involved in performance of such studies with the use of full-size buildings or rooms made it desirable to devise ways in which models can be effectively used for such purposes. The behavior of fires in enclosures of a simple type was studied. Variations were made in size of enclosure, size and shape of ventilation opening, and fuel loading. Analyses of fuel consumption rate and decomposition gas product data suggest that models may be successfully used to predict the behavior of fires in larger enclosures. There is, however, a considerable amount of additional work required before extensive use can be made of such models.

Fire Performance of Partially Dried Plasters. An investigation was made of the influence of moisture content on the fire endurance of partially dried gypsum plaster specimens. This work is needed to furnish technical information on the effect of fire testing building constructions before moisture equilibrium with the ambient atmosphere is attained.

The results show that when drying from both sides of the plaster specimen, under quiescent ambient air conditions, a minimum of 15 to 20 days per inch of plaster thickness is required for proper drying prior to test. The relationship between moisture content and fire endurance was not linear over the full moisture range explored. It was observed that small changes in moisture content near the equilibrium level had an unexpectedly large influence on fire endurance of such specimens.

Water Valves for Refrigerating Systems Studied. Refrigerant-pressure-actuated regulating valves are the principal means used to control the flow of cooling water to the condensers of mechanical refrigerating and air-conditioning systems. A laboratory study of several commercial makes and sizes of these valves was carried out at the request of the U.S. Army Natick Laboratories to identify the important performance characteristics and to provide information for specifications.

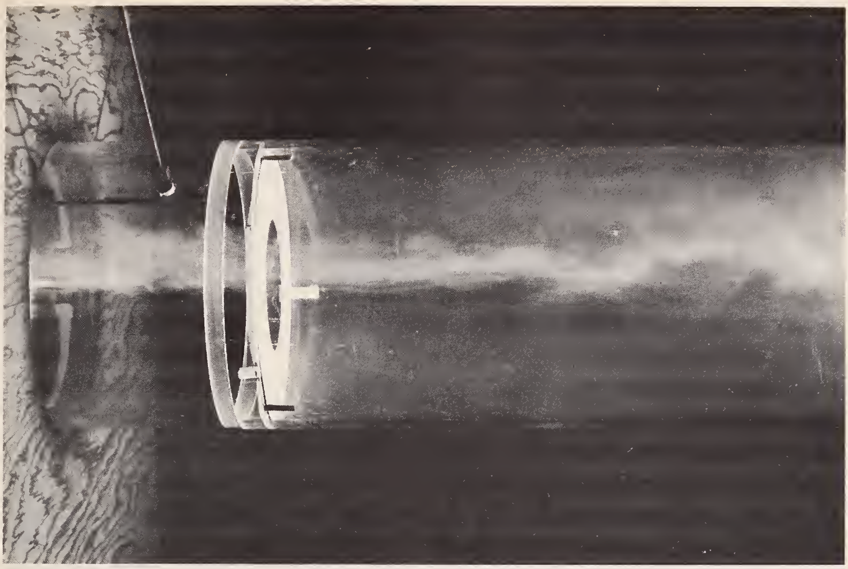
The investigation showed that the characteristics of importance included the following: (1) the water-pressure drop through the valve at maximum water flow rate; (2) the sensitivity of the valve in the working range of water flow rate; (3) the tendency of the valve to leak water at low refrigerant condensing pressures; (4) the decrease in sensitivity of the valve near the wide open position; and (5) slack in the moving valve element between opening and closing.

Thermal Properties of the Earth. Observed earth temperatures at 50 stations in the United States were tabulated for various depths ranging from 3 to 10 feet in most cases. Monthly averages covering several annual cycles are reported. A simple equation was fitted to the data for each station to develop design information on annual average earth temperature, the temperature variation from and lag behind average air temperature (at selected depths) based on the thermal properties of the earth, and the average temperature of the top 10-foot layer of earth for the month (August) when it was likely to be a maximum.

Although the data were collected and analyzed under the sponsorship of the Office of Civil Defense to provide needed design information for environmental control in underground fallout shelters, they will have broad value. The need for collecting additional earth temperature data to cover adequately the continental United States was revealed in the study.

Air Mixing Techniques Investigated. Methods for mixing moving air streams that are nonhomogeneous, with respect to temperature and humidity, are being investigated to provide greater accuracy in the testing of heating, air-conditioning, and refrigeration equipment that use air as a heat transfer medium. In a small apparatus designed for scale models, chemical smoke is used to simulate temperature or humidity variations in an air stream. The performance of a model mixer with smoke-laden air can be photographed or observed visually to assist in selection of the devices which appear to merit more comprehensive measurement in a full-scale apparatus.

The full-scale apparatus provides a stream of air of known velocity and measured inhomogeneity of temperature or humidity at the inlet to the mixing apparatus. It provides for measurement of the uniformity of temperature or



Model apparatus designed to measure the effectiveness of air mixers such as this square-edged circular orifice. Smoke is used to allow the mixing process to be observed visually. Mixers that show the greatest promise in the air-conditioning and refrigeration field are then subjected to extensive testing on full size equipment. **(See page 178)**

humidity downstream of the device, and the scale and intensity of turbulence produced by the mixer. Quantitative information on several mixers was obtained and some of the better designs were introduced into testing standards of the industry.

Asphalt Hardening with Reactive Oxidants. Asphalt is the most widely used roofing material in the United States today. For this purpose, asphalts are hardened by blowing with air at high temperatures (300 °C) and at high flow rates.

Recent research at the Bureau showed that, by replacing air with more reactive oxidants, asphalts can be hardened at a much faster rate while using temperatures 150 °C below those employed commercially, reduced gas flow rates, and simple apparatus. Effective oxidants were pure oxygen, ozone-enriched air, ozone-enriched oxygen, nitrogen dioxide, nitric oxide and oxygen, and nitrogen dioxide excited with a short wavelength mercury arc. The latter system required only 1/20 the reaction time needed with air to produce the desired hardening.

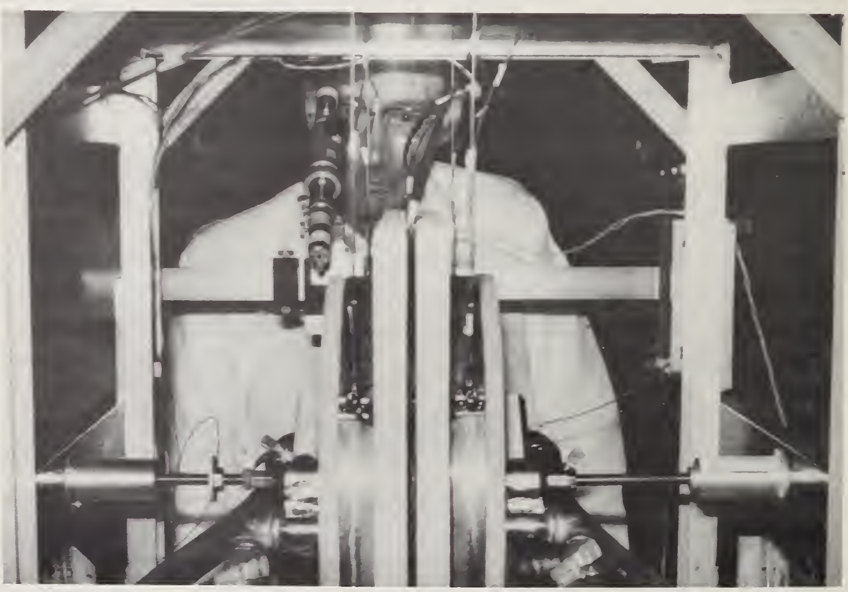
The roofing-grade asphalts produced with these oxidants were more stable to photochemical oxidation than were commercial asphalts from the same asphalt flux .

Building Codes and Safety Standards. Through membership in ASA standards committees pertaining to building and construction safety, the Bureau assists in the development of needed national standards. Recent work was undertaken to aid in reorganization of ASA Project A.112, Dimensional Standardization of Plumbing Equipment.

Measuring Thermal Conductivity of Materials. A new comparative method for measuring the thermal conductivity of insulation and many other building materials was developed. This method is reliable, precise, and relatively simpler than the standard guarded hotplate method (ASTM C177). Based on flow of heat in a conductive-disk hotplate, it requires only measurement of specimen thickness and a few steady-state temperatures.

A 12-inch diameter conductive-disk apparatus, made of a solid plate of low-conductivity metal, was constructed and compared with the NBS guarded hotplate. The ease of calibration, the quality of the results, and the speed with which they are obtained are all equal to or better than those for the standard test method. The demands on the operator's time are significantly less.

Moisture Condensation in the Insulation of Refrigerated Facilities. In many refrigerated structures, accumulations of ice or moisture develop within the walls as a result of condensation of vapor coming from the warmer side. These accumulations seriously reduce the insulating value, and often lead to deformations or physical injury to the structure. Corrective measures are usually difficult, and extremely expensive. Criteria which establish minimum properties of the vapor barrier, the insulation, and the interior finish, if any, required to avoid moisture condensation were developed on an analytical basis. It is hoped that with the criteria as a guide, designers of cold storage facilities can prevent difficulties in the future.



A newly developed comparative method for measuring the thermal conductivity of insulation and other building materials is more reliable, precise, and simpler than the standard guarded hot-plate method. Here, the average thermal conductivity of two pieces of one-inch thick insulation is being determined. The telescope is used to measure the thickness of the specimens under test conditions. **(See page 180)**

Long-Time Cement Test Program. Data collected from a long-time study of the performance of portland cements are being analyzed by a digital computer technique to find what correlations exist between the composition of portland cement, performance criteria of cements as measured by laboratory tests, and the performance of concrete made with the cements. Some 200 different cements were studied in the program.

Some of the minor constituents, whose presence in the cement reflects the geographical source of the raw material, were found to have a definite influence on the performance of the cement. Determination of these relationships will lead to future research on the manner in which certain minor constituents react with the major constituents to give the results observed, and may lead to the deliberate addition of certain minor constituents to produce improved cements.

Thermal Emittance of Cavities. Before accurate heat transfer calculations can be performed on building structures, the thermal emittance of the materials used in the construction must first be known. One of the most accurate methods of measuring this property is to compare the energy radiated from a specimen to that from a blackbody cavity (isothermal enclosure) at the same temperature.

Real blackbodies, because of the need for an opening, always provide less radiation than if the opening were not present. Theoretical expressions derived to compute the "apparent emittance" of cavities with openings do not always predict the same apparent emittance.

Recently, experimental measurements were made at NBS to test the validity of the various expressions. This was done through use of a reflectance approach. Spectral reflectances were measured from 0.4 to 0.75 micron for several cylindrical cavities of adjustable depth lined with different diffusely reflecting coatings. The resulting reflectances were converted to emittances by Kirchhoff's Law. Comparison of these experimentally determined cavity emittances with those predicted by the analytical expressions showed that two of these expressions gave excellent agreement. Therefore, either one can be employed with assurance in emittance measurements in which shallow cylindrical cavities are used as the reference standard.

Porcelain Enamel Institute Research Associateship Expanded. The current emphasis of the recently expanded Porcelain Enamel Institute Associateship is on the development of standard test procedures for such properties as weather resistance, alkali resistance and ease of cleaning. One program recently initiated is an exposure test to evaluate the weather resistance of the new porcelain enamels for aluminum. Exposure sites are at Washington, D.C.; Los Angeles, Calif.; New York, N.Y.; Montreal, Canada; and Kure Beach, N.C.

Cement-to-Aggregate Bond Tested. The irregular shapes and coarse surfaces of crushed stone and other concrete-aggregate materials make it very difficult to measure, to a satisfactory degree of precision, the effective surface area. As knowledge of surface area is essential to measurement of the bond strength between cement and aggregate, smooth $\frac{1}{4}$-inch-diameter

Exposing porcelain enamels on aluminum to determine their durability is part of a current NBS program to develop standard test procedures for such porcelain properties as weather resistance, alkali resistance, and ease of cleaning.
(See page 181)

spheres were used as aggregate in the development of a bond strength test method. The spheres were made of glass, steel, and two minerals frequently used as concrete aggregates. The test method involves comparison between the breaking strength of cement-aggregate bars and the strength of cement bars without aggregate.

Present concrete design practices with regard to strength are based solely on experience. It is hoped that the knowledge to be derived from this bond strength test will contribute to the development of a rational, workable theory on the strength of concrete. Such a theory would make possible fairly precise design, with increased efficiency and economy in the utilization of materials.

Granular Content of Sulfur Mortars Determined. The strength of sulfur mortars largely depends upon the ratio of the sulfur content to the granular materials. Many concrete-testing laboratories do not have the equipment or personnel needed to make determinations of this ratio by the ASTM carbon disulfide extraction technique. Therefore, a new method, developed by the Cement and Concrete Reference Laboratory at NBS, which is simpler and easier to perform, should be of interest to concrete testing laboratories and to industry as well.

In this method, a sample of the sulfur mortar is crushed and ignited, driving off the sulfur and leaving the granular materials. The ratio is determined by comparing the weight of the crushed mortar to that of the residue.

2.3.5. INFORMATION TECHNOLOGY

The Information Technology Division (formerly the Data Processing Systems Division) continues to serve as a central research and development laboratory in the field of automatic information processing within the Government. In support of its responsibility to provide advice and assistance, not only within the Bureau but also to other Government agencies, it conducts investigations leading to the development and design of new technological tools and techniques for more effective use of automation in processing information. It responds to specific requests for technical assistance and collaborates directly with the requesting agency in analyzing its operations to design or improve its information processing system. With the expanding use of information processing in Government and industry, the Information Technology Division has of necessity continued to augment its staff competence through specialized training and to increase the versatility of its research facilities.

The current program includes research and development activities using basic knowledge of such diverse scientific disciplines as physics, chemistry, electronic and mechanical engineering, linguistics, and the management sciences. Present activities include keeping up with new components and appraising their applicability in nanosecond computer circuitry; developing new techniques for the storage, processing, and retrieval of information; investigating ways of assembling components into prototype devices and systems; applying the techniques of communications and photogrammetry to information processing and control systems; developing automatic logging and preprocessing systems for scientific experiments; studying the man-machine interface; and applying automatic information processing techniques to the decision-making and technical support functions.

Research Information Center and Advisory Service on Information Processing (RICASIP). The Research Information Center, which has been sponsored jointly by the Bureau and the National Science Foundation since its inception in 1959, continued to maintain a file of the bibliographic references for information storage, selection, and retrieval, and for other areas of potentially applicable basic research. This collection now numbers over 15,000 references. The data file supports surveys, studies, and publications such as selected state-of-the-art reports and special bibliographies, as well as an index to the literature on legibility of alphanumeric characters and symbols.

During the year RICASIP cosponsored a Symposium on Statistical Association Methods for Mechanized Documentation, which was attended by over 200 specialists. Papers and panel discussions were presented during the three-day meeting by 35 leading workers in the field.

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Standardization Activities. Members of the staff participated in committees, subcommittees, and task groups of the American Standards Association, activities concerned with establishing standards related to computers and information processing, data transmission, communications systems performance, character sets and data format, definition of controls, machine indexing, abstracts, computer programming languages, and glossary terminology. A senior staff member served as the first chairman of the newly formed ASA Information Processing Systems Standards Board and another member of the staff was U.S. Delegate to the International Organization for Standardization Technical Committee on Computers and Information Processing.

Processor Programming Research. Research continued on advanced programming techniques to improve communications between people and computers, between data acquisition devices and computers, and between computers and devices which they control.

Numerous models and diagrams representing populations, mazes, a manufacturing process, graphs, electronic circuits, and simple rectangular figures were studied. Ciphers which are acceptable to a computer were devised for each model or diagram considered. The requirements for manipulating these ciphers in a computer were studied and some subroutines for performing these manipulations designed. The language for using these subroutines is computer-independent, enabling the user to manipulate the subroutines by means of terms that are common to his special field. A trial language called SYNCRETIC was developed and existing research tool languages IPL–V, COMIT, LISP, and SIMSCOPT were studied.

Studies of Components and Materials. The study of new and existing components continued as basic to developing faster, cheaper, more reliable, and more efficient digital data-processing devices. Magnetic film materials in particular were studied and a survey of those having possible applications in digital computer technology was prepared for publication. A technique for measuring the ferromagnetic exchange constant of a magnetic film with a conventional hysteresis loop tracer was developed by making minor equipment modifications. The measurements that can now be made should yield information that will aid in characterizing magnetic thin films.

Specific efforts by two staff members were directed to maintaining current awareness of the latest components, devices, and circuit techniques, noting progress in integrated circuits, discrete-component modules, planar-epitaxial transistors, charge-control diodes, tunnel diodes, backward diodes, and hot-electron diodes. Anomalous temperature behavior in transistor-tunnel diode circuits is being investigated.

Tunnel diodes and transistors were utilized in designing a binary counter capable of operation beyond 100 megapulses per second. A reset-set (R–S) type of flip-flop was investigated for use in gating circuits for a shift register capable of operating at more than 50 megapulses per second.

Computer Input-Output Devices. Novel input and output devices for computers are being studied in terms of their effects on the computer-operator interface. Particular attention was paid to computer operation with pictorial inputs; means of generating displays of symbols, line drawings, and contours; and use of magnetic tape and photographic devices for transferring data between man and the digital computer.

Technical Assistance for NBS Data Processing. New areas for the application of automatic data recording and processing were developed in collaboration with other laboratories of the Bureau to solve their data-handling problems. Some of the applications presented special data-logging and preprocessing problems. Systems were devised for collecting data from an automated infrared spectrophotometer (see p. 57), from crossed-beam collision experiments simulating the upper atmosphere (see pp. 90 and 94), and from infrasonic noise receivers (see p. 62).

Much of the equipment required for recording these data automatically was assembled from previously designed modules making use of standard circuit cards. New modules designed and implemented during the year include a digital magnetic tape transport, a ripple register, and an up-down counter with built-in shift capability. The new circuit cards designed include a matrix card, dual comparator, reed relay card, up-down counter, digital switch, dual high-impedance amplifier, and a crystal oscillator. Some of the new and previously developed modules were added to the on-shelf stock available to Bureau laboratories on a short-term loan basis for assembly into their systems.

The information technology staff also furnished engineering assistance to the Bureau's high-energy radiation laboratory in planning and assembling digital circuitry for processing the input to a computer-controlled data-logging system. Additional advisory services were furnished in planning programs and procedures enabling the experimenters to intervene in the computer operation.

Automatic Indexing by SADSACT. A machine program for automatically assigning descriptors to technical articles was developed and is now being tested. The program, called SADSACT (*S*elf-*A*ssigned *D*escriptors from *S*elf *A*nd *C*ited *T*itles), "learns" associative links by inspection of previously formed pairs and then selects descriptors for words comprising new items.

In the first step the program directs the machine in compiling a master vocabulary, listing for each subject word all descriptors which occur with it often enough to be significant. The machine does this by analyzing an input "teaching sample," consisting of multiword entries paired with descriptors previously assigned by indexers.

The computer reads in from punched cards the items for which descriptors are desired, searches the vocabulary for each word of each item, and sums the number of times each descriptor was found for each item. The program then selects for each item the several descriptors found with greatest frequency.

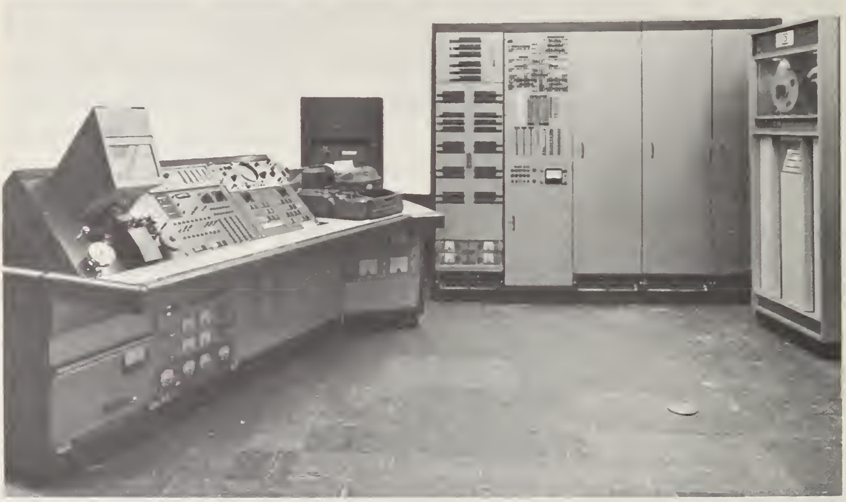
The program was tested after the machine was loaded with teaching samples from a variety of subject fields which had been previously indexed at the

Defense Documentation Center. Test samples included scientific papers (for each of which the title, abstract, and titles of references were included) and news items; the descriptors assigned were in substantial agreement with previously made assignments. Further tests, on more homogeneous subject matter, are now in progress under a grant from the Council on Library Resources.

Automation of Chemical Search Operations. The Bureau is engaged in continuing research, in collaboration with the Patent Office, on methods of automating operations involved in processing patent applications. A large part of the patent application workload could be more readily processed if the Patent Office had a speedy and sure way of automatically searching its data on chemical compounds. The Bureau is working on this retrieval problem also for the Army Research Office, since retrieval of chemical information is essential to many research programs of the Department of Defense.

Automatic searching requires that chemical structures be represented in a manner capable of being encoded in digital form for computer manipulation. The Bureau's previous work in this area led to the development of HAYSTAQ, a computer program for searching chemical data by means of structure fragments encoded in digital form. Subsequent work at the Bureau, the Patent Office, and elsewhere produced notation systems for identifying whole structures. Much of the present work at the Bureau is devoted to transforming the alphanumeric notations into a form that computer programs can use directly.

Organic structures can be described by Hayward linear notations, the rules



An example of NBS assistance in solving information processing problems for other Government agencies is ACCESS. This high capacity, multipurpose, data-conversion and editing system was developed and built for the Office of Emergency Planning for handling resource-evaluation and status information.

(See page 188)

for which were originated at the Patent Office, and by Wiswesser notations, both of which the Bureau is now studying. The original Hayward rules have been simplified for some complex structures and new rules devised to extend the notation to features not originally covered. Notations for describing complex inorganic compounds are being developed by the Bureau and the Patent Office.

The Bureau is embodying algorithms (precise logical processes) in computer programs which automatically translate from the alphanumeric linear notations to HAYSTAQ-type "connection tables" encoded on an atom-to-atom basis, rather than by structure fragments.

In other work sponsored by the Patent Office the Bureau is studying by means of Boolean matrices the theory of files containing interrelated entries. It is also developing techniques for the organization of very large files of interrelated information, under sponsorship of the Army Research Office. Findings from both studies are expected to affect the manner chosen for the computer to store and process related data such as chemical structures, methods of manufacture, and biological activity.

Automatic Character Recognition. The Bureau continued a literature search and survey of equipment developments for recognizing printed characters, sponsored by the Department of the Army. A corollary task was the development of a "syntactic analysis" technique for recognizing the pictorial configurations of components of Chinese ideographs. A list of approximately 300 radicals and radical-like components and rules governing combinations have now been developed which account for more than 80 percent of the characters in common use. These rules were tested in a preliminary computer program using cases in which a machine recognition scheme would not be able to decide between several alternatives. The method facilitated error detection and in some situations error correction.

Simulation of a Communications System. TELETRAF a computer program capable of simulating portions of the Defense Communications System (DCS), was devised and used at NBS to render technical assistance to the Defense Communications Agency (DCA). The DCS is a worldwide communications system, a composite of the separate long-line systems of three Services, providing regular and emergency communications. A flexible method of evaluating potential sites and configurations is essential for the DCA to set up a system that is as catastrophe-proof as possible.

The Bureau also developed a computer program written to accept nuclear attack data as input and produce a tape driving a plotter printing map overlays showing areas of possible destruction. These can be used to specify system features that probably would permit maintenance of a given grade of service. They were used in experimentation with several vulnerability-simulation models.

Detection of Nuclear Events. The development of a data acquisition and processing system for the detection of nuclear events in space was begun under the sponsorship of the Advanced Research Projects Agency. The system will be used with a large number of geophysical sensors to study the natural background for each variable and to determine useful discriminants. The system design consists of a hybrid analog-digital system selecting sensor outputs occurring on a short time scale for recording by analog techniques. Digital techniques will be employed where inter-sample intervals as large as a millisecond can be tolerated. This system will use an on-line, computer-centered digital data acquisition system, the operational requirements for which were established. The system will filter raw data to extract special events on a real-time basis, minimizing the volume of data retained for subsequent analysis.

Two data logging systems assembled from NBS modules will be used for data acquisition pending installation of the computer and will then be retained as backup systems for use during routine maintenance of the computer.

ACCESS. An Automatic Computer Controlled Electronic Scanning System (ACCESS), a high-capacity, multipurpose data-conversion and editing system, was completed and delivered to the Office of Emergency Planning. This system, developed for handling resource-evaluation and status information, reads data from 16-mm microfilm of marked documents. It performs such general-purpose computer tasks as code conversion, verification, editing, summarizing, reorganizing, screening, storing, message preparation and transmission, and control of input-output devices such as X–Y plotters, magnetic tape units, and communication facilities. Its modular design permits the system to be tailored to the requirement of various local, regional, or central data acquisition links within a complete organizational network. The use of microfilm as a storage medium facilitates access to data by both man and machine without any intermediate conversion of data. This allows decision-making by men or by an electronic computer.

Completion of a set of routines for the central processor and scanner diagnosis made possible experiments in which line drawings and map tracings were read by the computer-controlled scanner and digitized in the output as X and Y coordinates. In this form they are suitable for automatic use, storage on magnetic tape, or plotting on an X–Y plotter. Good reproductions of inked tracings of closed contours and geographic outlines were obtained from the originals stored on 16-mm film.

Global Space Information. A global-range information-processing and control system for future orbital and space programs will require expansion of present capabilities. Such a system was planned for the Air Force to control instrumentation and data-handling equipment, to determine information-forwarding priority, to recognize the urgency of incoming information, to make best use of available communications facilities, and to keep control centers informed of information network status.

Work on this project includes defining the problems of integrating the functions and facilities of military missile and space ranges in addition to studying computer languages, file manipulation, and generation of encoded commands. The Bureau defined four elements of a range instrument control loop—central terminal logic and instrument control sequencer, station terminal logic, site instrument control, and message composer—and started their detailed functional design.

Naval Procurement Procedures. The Bureau assisted the Navy's Bureau of Supplies and Accounts in developing data-handling techniques and devices for an efficient system for procuring and distributing the thousands of items used within the Naval establishment. Present procedures at a Naval supply center were surveyed and available input-output devices adaptable to the supply system examined; these included keyboards, printers, and card printers and punches. Interface requirements for a future "real-time" supply record system providing overall coordination of this Navy activity were defined.

Remote Inquiry Stations. A remote inquiry station was designed, under joint sponsorship of the Patent Office and the Bureau, as a means of communication between human operators at various locations and a central data processor; a prototype model is now being fabricated. Such stations could be located within one building or separated by distances of hundreds or thousands of miles to enable people to use the computer from wherever the information is required. By facilitating access to the computer such a development could multiply the usefulness of an information storage, search, and retrieval system.

The Vigilometer. The Bureau completed the Vigilometer, a complex device for presenting audio and visual stimuli to a subject and recording his responses, and delivered it to the Army Personnel Research Office. It is

The Vigilometer is used in testing a subject's responses to various visual and auditory stimuli. It was developed for the Army Personnel Research Office to measure attentiveness and fatigue thresholds. **(See page 189)**

now being used as a tool for research in vigilance and fatigue threshold determination. This system consists of five subject stations, each with five stimuli generators, and a central control console. Digital logic circuitry under control of a prepunched paper tape program activates stimuli for any time period up to eight hours. Responses are recorded by a column printer for analysis by the researchers.

In other work for the Army Personnel Research Office, the Bureau applied computer techniques to psychometric testing. It performed a design study on this means of overcoming many limitations in presently used printed tests and answer sheets.

Processing and Storing Microfilm. The Bureau continued to provide technical advisory services to the Weather Bureau on transmitting and processing photographic data acquired by weather satellites of the NIMBUS series. The services included technical advice on storage of microfilmed archival cloud analysis data.

Three-Dimensional Information from Photographs. The Bureau continued research on techniques for scanning aerial stereophotographic information under the sponsorship of the Naval Training Device Center. The object of this program is to use the scanned information for automatically producing three-dimensional terrain information. Experimentation with computer programming led to the development of techniques for computer recognition of conjugate points of an aerial stereophoto pair. This, in turn, permits the determination of parallax and computation of X, Y, and Z-axis information about the subject terrain.

Management Data Processing. Advisory service was given also to the Internal Revenue Service in setting up and administering a comparative study of the efficiencies of processing tax return information on three different kinds of manually keyed machines. The study report compared performance on identical practice material using a 10-key adding machine, a 14-column (full bank) machine, and a keypunch-verify machine. The results showed that the punch-and-verify process is significantly slower and no more accurate than either of the other two used in the experiment.

Computers in Management of Recreational Facilities. The Bureau studied the feasibility of using automatic processing techniques in the development and management of a nationwide plan for outdoor recreation facilities at the request of the Bureau of Outdoor Recreation, Department of the Interior. An inventory must be made of existing and potential recreation areas, because of the need for planning future outdoor recreation facilities for the increasing population. The inventory will be used in an analysis of present facilities and along with demand data (population and socioeconomic factors, for example) will aid in projections for future recreation needs. A computer program was written for maintaining a file of about 5,000 recreation areas of over 10 acres, from which current information and statistical data on sites can be extracted. Members of the Bureau of Outdoor Recreation staff were also given training in general computer techniques and programming.

Automatic Data Processing for Public Housing Administration. Technical assistance was continued to the Public Housing Administration in data processing techniques and programming for tenancy reports. Local housing authorities are required to submit reports about applicants and present tenants in low-rent housing annually for review of tenant eligibility. Computer programs were used in processing data on approximately 450,000 re-examinations and 12,000 new tenants.

Survey of Federal Information-Storage Systems. The Bureau prepared case studies of Federal information storage, selection, and retrieval systems either in being or in planning. This was a preliminary in the design of an improved information-handling system for domestic and international business figures in the Department of Commerce Office of Administration for Domestic and International Business. The information systems of the Department of State and the Small Business Administration were studied. Studies of systems currently in use in planning by the Central Intelligence Agency, the Food and Drug Administration, and the Securities and Exchange Commission are now in progress.

Data-Handling Systems for the Office of Technical Services. The Bureau concluded its work on the design of an information management system for the Office of Technical Services for acquiring, advertising, and disseminating reports on Government-sponsored research and development. This included a computer program for the automated preparation of integrated cumulative indexes and a simple manual inventory and order-handling system capable of the required performance for an increased number of documents.

Automatic Mail-Sorting Developments. The Bureau continued assistance to the Post Office Department in applying automatic data-handling techniques and equipment to the improvement of mail-sorting and route-selection operations. The manual sorting schemes now used at Washington, D.C., were adapted for use with prototype codesort equipment by listing each possible address (individually or in a group) on magnetic tape with bin assignments. Final procedures were developed for updating these lists by use of a computer.

Transportation network relationships were mathematically analyzed for finding the Post Office location having minimum transportation costs for getting the mail to its patrons. The mathematical model and computer program written indicated that for a considerable area around the minimum point the costs would be close to minimal.

A previous analysis of a buffer problem in matrix-type sorting machines was extended to a buffer which helps prevent overflow within a proposed package-sorting machine. Buffer problems between stamp cancellation and first sorting and the amount of storage capacity needed in a mail separator machine also were investigated by use of computer simulations.

The relative merit of reading addresses by optical character readers attached directly to sorting machines or operated separately was investigated.

Sorting systems are being developed for both configurations to determine the comparative costs.

The Bureau developed a model of a novel sorting concept involving a device called a director. The Post Office is using the model to evaluate the economic merits of the system. Its use would eliminate the cost of transferring mail among machines within a sorting system, but would require additional machinery.

A method for estimating the time required to process a letter through a selected subsystem was developed. This is a statistical sampling procedure, by use of which it can be determined if the time for a particular letter is greater or less than a predetermined time. It will be useful in time and flow comparison studies.

Technical advice was also given on human aspects of postal machinery design and evaluation. Advice on such factors was specifically requested in the conduct of three machine evaluation programs and in areas related to man-machine interface.

2.3.6. INSTRUMENTATION

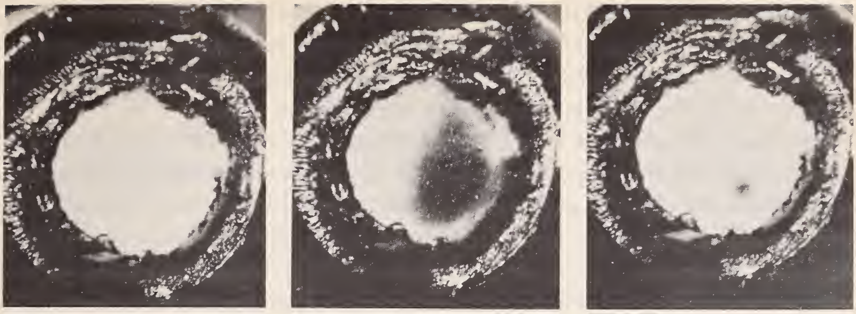
The Bureau is concerned with both the theory and practice of measurements; its practical work is aimed at improving both industrial technology and the Bureau's own research programs. Since measurement precision depends on the natural limitations of the method and the behavior of practical instruments, both are being investigated to advance the measurement art.

The Bureau maintains an extensive reference file of literature on instruments and measurement methods to help disseminate measurement information and avoid duplicating scientific research effort. The file is designed so that its data can be retrieved partly by mechanical means. Simple techniques insure good coupling between the researcher and the file, so that the researcher is led quickly to relevant information.

Mechanical instrument activities include responsibility for the national standards of humidity and for improvement in standard hygrometers and humidity generators. Calibration methods are being developed for pressure an acceleration transducers, while other mechanical instruments are being developed to meet specific Federal agency needs.

Electrical and electronic methods are widely used in modern instrumentation, even when the initial phenomenon being measured is not electrical in nature. Electronic methods were devised to investigate the characteristics of materials used in vacuum systems, as well as the characteristics and capabilities of electron devices themselves. Improved electronic instruments were developed not only for use in Bureau research programs but also for use by other Federal agencies.

Project FIST. The original object of Project FIST (*F*ault *I*solation by *S*emi-Automatic *T*echniques), supported in part by the Navy Bureau of Ships, was to develop techniques that would permit a relatively untrained technician to locate faults in electronic equipment. Work has shown that



The distribution of current in a transistor can be "seen" by coating its active portion with a phosphor whose luminescence under ultraviolet irradiation decreases as the temperature increases. Hot spots accompanying current flow become visible as dark areas. From left to right are transistors carrying no current, high current, and current in the area of second breakdown, show as a dark spot. **(See page 194)**

this object can now be reached easily, and the goal has been expanded to include techniques that will produce diagnostic data, which the trained technician can use to make maintenance decisions.

The untrained technician will use *good-bad* indications from the general-purpose test set and ignore other data that the test instrument can supply. As he grows in competence he can use additional information from the test set to increase his effectiveness as an electronic maintenance technician. In this way FIST will be more generally useful as a diagnostic tool and will counter prejudice which the technician might have against using a test instrument permitting him to make no decisions.

Precise Electrical Characterization of Semiconductors. Methods and techniques are being studied, in a program supported by the Advanced Research Projects Agency, to improve the fundamental accuracy with which the electrical properties of semiconductors can be measured. These properties include minority carrier lifetime, carrier mobilities, and resistivity at various temperatures. In response to industry's most important need, the program concentrated chiefly on room-temperature resistivity measurements of silicon by direct-current techniques in the 0.1 to 10 ohm-centimeter range.

Three methods are of major interest: the four-point probe, the two-point probe, and the van der Pauw technique. The van der Pauw technique has the advantage that only one-dimensional measurement (thickness) of the sample is necessary. The two-point probe has the advantage of greater accuracy when used on a nonuniform sample. The four-point probe has the advantage of great convenience as a routine technique plus the ability to resolve resistive nonuniformities.

The Bureau study concentrated on the effects of sample surface finish and probe material, the problems involved in sample nonuniformity, and the geometrical correction factors. Computing facilities available at the Bureau were used extensively in this work. The ability of the four-point probe to detect nonuniformities was clarified and knowledge of four-point probe correction factors has been extended, enabling better comparison of four-point and two-point probe measurements made on the same sample. The search for more uniform material on which to make comparative measurements led to study of samples doped by neutron irradiation and of samples doped with boron or aluminum and grown by special techniques.

Second Breakdown. A study of the transistor operating mode known as *second breakdown,* begun at the request of the semiconductor device industry, was continued under sponsorship of the Rome Air Development Center. The onset of second breakdown is marked by a decrease in collector junction voltage and a constriction of minority-carrier current in the base. It was found that the mode appears above a threshold power level and has a starting delay. Operation in this mode can damage the transistor, and its inadvertent onset causes circuit malfunction. Second breakdown, therefore, is a matter of concern to both industry and its customers.

The investigation of second breakdown led to a better understanding of its characteristics. Temperature-sensitive phosphors with a short response time were used to display transient current distributions in transistors by means of the associated temperature distributions. The influence of structural defects and base drive on the development of second breakdown is now better understood. It was found that the base current can control the fraction of total current that flows through the current constricion and can so reduce this fraction that the transistor will revert to a normal mode of operation.

The Bureau participated in meetings of the Joint Electron Device Engineering Council charged with specifying operating conditions under which second breakdown does not occur. The Bureau also proposed a definition of second breakdown for adoption by the International Electrotechnical Commission.

A cooperative program with industry is aimed at finding whether a relation exists between the appearance of second breakdown and the existence of strains, dislocations, and other imperfections in the transistor.

Peak-Reading AC-DC Comparators as Laboratory Standards. An ac-dc comparator was developed for the Bureau's Electricity Division as part of a study of peak voltage measurements. Previous developments along these lines at the Bureau include a differential thermocouple voltmeter for transfer measurements of audiofrequencies by comparison with direct current standards, with a repeatability of better than 20 parts per million (ppm). This technique makes the comparison on a root-mean-square basis, but a sinusoidal voltage can be specified as well by its average rectified value or its peak value. The average or peak measurement is often an easier one to make in the field.

Audiofrequency generators recently became available with amplitude stabilities and total harmonic distortions of less than 100 ppm. These generators make it worthwhile to investigate improvements in both average- and peak-reading measurements.

The essential feature of the new ac-dc comparator is a high-speed synchronous switch that samples the sinusoid voltage for a short interval in the region of its peak. The switch alternately samples a precise dc supply. The two samples are compared by means of an oscilloscope; the visual comparison allows a precise value to be assigned to the peak of the ac waveform. Preliminary results are repeatable to 20 ppm, using the thermal transfer technique as a standard. Additional noise reduction in the ac generators might permit precisions of better than 10 ppm.

VHF Spectrum Analyzer. A spectrum analyzer was designed and built for use in studies of the output power spectrum of a helium-neon laser at the Bureau's atomic physics laboratories. Part of a laser's output radiation, at a wavelength of 1.15 micrometers, is intercepted by the cathode surface of a photomultiplier tube. The electrical output of the photomultiplier consists in part of intermodulation difference-frequency components that correspond with the line separations of the laser's output spectrum. The purpose of the analyzer is to examine these intermodulation components in detail.

The analyzer, a frequency-sweeping type, accepts inputs within a 5-MHz range centered at either 150 MHz or 300 MHz. The swept bandwidth can be selected in ranges from 200 Hz to 200 kHz with resolutions from 2 Hz to 20 kHz. The amplitude-*versus*-frequency spectral response is displayed on an oscilloscope.

FOSDIC Applications. The FOSDIC III equipment (*F*ilm *O*ptical *S*ensing *D*evice for *I*nput to *C*omputers) was developed in a joint effort with the Bureau of the Census for use in the Decennial Census of 1960. It has since been applied to many other projects for which NBS continues to supply consulting services.

A recent large-scale project involved identifying the serial numbers on the mailing labels of questionnaires mailed back to the Government. The serial numbers were coded in binary form in an extra line of selected typewritten characters on each label. By scanning the upper portions of the characters, FOSDIC is able to derive the original number. In this manner, the returned questionnaires can be checked off against a master list by machine.

FOSDIC was also used to scan the film records of instruments that measure the direction and speed of water currents. For this application, a special attachment was developed to allow the FOSDIC equipment to handle motion-picture film.

FOSDIC has been used experimentally to recognize handwritten characters. The machine can recognize all letters and numbers of a set of written characters if the writer accepts constraints on the style of character formation.

A new scanner, a transistor version of the scanner in FOSDIC III, was completed and made an operating part of the ACCESS system (see p. 188). In addition to its use for acquiring data from documents, it can be used for general-purpose scanning of patterns or line drawings.

The machine development sponsored by the Weather Bureau, FOSDIC IV, was completed and made ready for delivery to the National Weather Records Center at Asheville, N.C. This machine scans microfilm copies of punched tabulating cards, searching for selected data. Output can be on magnetic tape or punched cards and can include part or all of the data on the input films.

Vacuum Physics. Many measurements in the very rarefied gas environment, including the calibration of gages and the measurement of throughput, depend on a detailed knowledge of mass transport through bounded regions. However, the expressions for transport have been developed only for limited geometries; only the long tube has had even moderate experimental study. It is desirable to test transport concepts to greater accuracy and at lower pressures than has been done before as a function of geometry, surface condition, gas species, and temperature.

Substitution techniques are being studied as a method of precise measurement. A linear flow line was used for the purpose, and effects on its behavior of various factors were investigated. These included flow stability, pump behavior, ionization gage sensitivity, and temperature. Transient response also was studied. Stability, sensitivity, and resolution of better than 0.1 percent at 10^{-5} torr were achieved, and the line was shown to be linear within these limits. The substitution procedure is independent of ionization gage pumping or other extraneous flows, provided they are constant during the period of measurement. Ionization gage drift was examined and none found until pressure changes greater than 2 percent were made at 10^{-5} torr. The relaxation effect of about 0.2 percent found under these conditions was ascribed to sorption kinetics

2.4. CENTRAL RADIO PROPAGATION LABORATORY

The Central Radio Propagation Laboratory (CRPL), located at Boulder, Colo., has the primary responsibility in the U.S. Government for collecting, analyzing, and disseminating information on the propagation of radio waves at all frequencies along the surface of the earth, in the atmosphere, and in space. It also conducts scientific studies directed toward new techniques for the efficient use and conservation of the radio spectrum.

The radio-frequency spectrum, like other critical resources, is essential to our well-being but is limited in extent; it is not adequate to meet all conceivable future needs. We cannot enlarge the spectrum beyond its present limits, but we can expand its usefulness through scientific research and development, and conserve it by planning and allocating it to more essential requirements.

CRPL is responsible for assisting administrative and operating activities of both Government and industry in the field of radio propagation. It does this at the international level by active participation in the work of the International Scientific Radio Union (URSI), and from the International Radio Consultative Committee (CCIR), the engineering organization of the International Telecommunications Union. Eighteen members of the CRPL staff were selected by the National Academy of Sciences to be members of the U.S. delegation to the General Assembly of URSI in Tokyo in 1963.

Members of the CRPL staff direct the CCIR standards and international allocation work in the United States in the fields of radio systems, tropospheric propagation, and ionospheric propagation. The work is coordinated in this country by the Department of State. Eight members of the CRPL staff were selected to be delegates to the CCIR Plenary Assembly held in Geneva, Switzerland, in 1963.

During the past year CRPL revised a chapter dealing with propagation and technical factors in radio spectrum utilization in the book entitled *Radio Spectrum Conservation.* The book was originally published in 1952 as a report of the Joint Technical Advisory Committee of the Institute of Radio Engineers (the IRE, now merged into the IEEE) and the Electronic Industries Association. The revised chapter employs a systems approach by frequency band, starting at the very lowest radio frequency used for telecommunication purposes and proceeding to higher frequencies.

Project HANDS, High-Altitude Nuclear Detection Studies. One of the most important of CRPL's present activities is HANDS, a project which draws on the services and cooperation of the staffs of many groups in CRPL and also in the Institute for Applied Technology. Project HANDS was undertaken this year for the Advanced Research Projects Agency and is now in operation. Its purpose is the development and evaluation of methods of detecting high altitude nuclear detonations by continuous monitoring.

A new building at the Table Mesa (Colo.) field station now houses the sensors being evaluated, data-processing equipment, and recording equipment. These sensors measure phase and amplitude variations of radio waves received at steep and oblique incidences, ionospheric absorption of cosmic radio noise, air fluorescence at 3914 Å, and electromagnetic pulses. Measurements of variation in magnetic field and infrasonic and acoustic disturbances, being obtained in other NBS programs, also will be used in this program.

Present information indicates that a nuclear detonation can be most readily recognized by means of the prompt effects produced by its x rays. Measurements of normal values and those incorporating solar disturbance effects are now being processed by an analog-to-digital converter and recorder developed at the Washington measurements automation laboratories for this program. The data are encoded on magnetic tape, which is processed by a computer programmed to search for events of interest—those having rapid rates of onset, higher-than-normal amplitude, or abnormally long durations.

A more elaborate system has been designed and will be placed in operation when the new computer is received. Data from each sensor will be recorded routinely every 5 seconds until an interesting event is detected by the on-line computer. The computer will then place the system into accelerated operation to record more detailed data on all channels. Full-scale data acquisition is planned to begin in January 1965.

IQSY—The International Years of the Quiet Sun. IQSY is a period during 1964 and 1965 which is characterized by a lull in solar radio activity and hence permits studying phenomena which are obscured by normal solar activity. Like the IGY (International Geophysical Year 1957–58) which occurred at a maximum of solar activity, the IQSY is being conducted on an international basis. Scientists from more than 65 nations are making measurements, under this coordinated program, in a variety of disciplines concerned with solar and terrestrial physics. Measurements are being obtained from many of the IGY station locations and collected at many of the IGY data centers. CRPL is operating World Data Center-A for Airglow and Ionosphere and participating in the operation of World Data Center-A for Solar Activity. The National Science Foundation is partially supporting continued operation of these data centers.

The success in some fields of the IQSY depends on making observations when the desired types of solar and geophysical activity are taking place. A listing of such periods, the "Abbreviated Calendar Record," is prepared by the NBS Radio Warning Services from telegraphic reports and published regularly in *IQSY NOTES*. It includes comments of the IQSY World Warning Agency, provided by the NBS North Atlantic Radio Warning Service at

Fort Belvoir, Va. This group also assigns designations to all satellites and space probes for the international Committee on Space Research (COSPAR) and distributes satellite launching and orbit data internationally.

IGY—The International Geophysical Year. CRPL continued to operate IGY World Data Center-A for Airglow and Ionosphere and the World Data Center-A for Solar Activity (in part), with financial assistance from the National Science Foundation. These data centers are not only processing IQSY data, but are still occupied in cataloging, copying, and distributing IGY data to scientific and technical groups.

During 1964 approximately 3,500 "station-months" of data were examined by CRPL staff and visiting scientists; about 9,000 station-months were supplied in response to requests; and 25 scientists from other groups visited the data center, staying an average of 5 days each.

2.4.1. IONOSPHERE RESEARCH AND PROPAGATION

Since the time of Marconi's first transmission and reception of radio waves across the Atlantic Ocean, reflection of radio waves by the ionosphere has played a crucial role in long-distance communication, serving important needs which land-line and submarine cable could not meet. In the future, satellite relays, which do not depend upon ionospheric reflection, will undoubtedly assume a large share of the burden, but communication engineers realize that for many years yet to come the ionosphere will continue to play an important and exclusive role. Under the broad heading of Ionosphere Research and Propagation, the Bureau conducts and coordinates studies of the ionosphere and its effect on the propagation of radio waves. The basic nature of ionospheric radio propagation is well understood; the main problem is to understand the processes responsible for the complexity and variability of the ionosphere and to learn to predict the ionosphere's net effect on radio waves.

Vertical Soundings Research. The technique of vertical ionospheric sounding, in which radio energy is transmitted straight up and the returned energy monitored, is used extensively by the Bureau in studies of the ionosphere. Recently the Bureau launched a broad attack toward understanding the processes occurring at heights of 100 to 900 km, which are involved in the "continuity equations" for electrons and ions. This led to identification of the conditions—largely various ion composition ratios—under which the law of electron disappearance would approximate that observed in the ionosphere.

Study of electron density data from vertical soundings disclosed geographic and seasonal variations in neutral composition of the atmosphere which may be identified with large-scale circulation and mixing processes. In other work, ionization by electrons "dumped" from the Van Allen radiation belts was advanced as the cause of the puzzling persistence of the ionospheric *F* region during polar winters.

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Plasma Resonances in the Ionosphere. Resonant oscillations of the ionospheric plasma excited by high-frequency radio pulses were observed by topside ionospheric sounders carried aloft first in CRPL rocket tests and later by the United States-Canadian topside sounder satellite, *Alouette*. Two years after first being observed, these resonances were correctly identified as lying at the plasma frequency f_N, the electron gyrofrequency f_H and its harmonics, and at a so-called hybrid frequency f_T.

These resonances are explained on the basis of existing theories of plasma oscillations (simplified by the almost collisionless state of the upper ionosphere) as involving electrostatic oscillations of the plasma with the electric field of the electrons providing the restoring force. Resonances at f_N and f_H correspond to oscillations along the magnetic field and at f_T and nf_N to those across the field. Oscillations at intermediate angles also are believed to be excited, but to disperse away from the satellite too rapidly for observation.

An electron density probe utilizing the plasma resonances is being developed in a program sponsored by the National Aeronautics and Space Administration. Such a probe will be particularly useful at the very low plasma densities in the magnetosphere and interplanetary space, where other kinds of probes encounter difficulties.

Persistence of Solar Flare Activity at Fixed Longitudes. Solar flares that emit sub-relativistic protons are observed to prefer certain locations on the sun, at which new centers of intense activity break out repeatedly over the years. The pattern is related to previously recognized sunspot clustering in certain solar longitudes. NBS is studying these characteristics for help in predicting solar proton events and understanding the solar processes responsible for the acceleration of particles and the formation of flares.

Active Dark Solar Filaments. Sudden changes in dark filaments on the solar disk were found to be closely associated with bursts of radio noise of centimeter wavelength. Such changes in the filaments (which would appear as prominences at the limb of the sun) also occur at the time of solar flares. The observed relation is interpreted to mean that a change in the magnetic field structure in the chromosphere near the flare is a necessary condition for acceleration of the fast particles that excite the radio burst, as well as for the sudden changes shown by the filament.

Noise Storms in the Solar Atmosphere. The apparent height of each of about 30 solar noise storms was deduced by comparing its rate of travel across the solar disk (determined from published position measurements) with the rate of travel of the solar surface. The heights ranged from one-tenth to one solar radius above the photosphere. These estimates for individual storms in the solar corona give added insight into the emission and propagation of the radio noise which often accompanies the ejection of solar particles. Earlier analyses of combined data failed to produce the important information provided by this study of individual storms. Study of the individual heights has led to a description of how intensity and change in

Solar flare and ejection that produced high-energy protons. These cosmic-ray flares occur preferentially at certain longitudes on the sun. NBS is studying these characteristics for help in predicting solar proton events and understanding solar processes. (High Altitude Observatory Photograph.) **(See page 200)**

position depend on storm height, and also to the discovery of a variation of average height during the solar activity cycle.

VLF Observations of Solar Flare Ionization in the D Region. During most solar flares, new ionization is produced below the normal *D* region over the sunlit hemisphere. The normal *D* region is thought to be formed by ionization of the atmospheric constituents by solar Lyman-alpha emission and cosmic rays, but this radiation is not adequate to explain the abnormal *D* region produced during a solar flare. Recent rocket and satellite observations during solar flares have given support to the suggestion that the enhanced *D*-region ionization during solar flares is due to x rays.

Recently the phase and amplitude variations of phase-stabilized VLF transmissions over six long propagation paths were observed. This network permitted variations occurring over approximately one quarter of the earth's ionosphere to be sampled and thus provided an excellent means for studying the effects of solar flare ionization over a large area of the ionosphere. During 1961 multiple simultaneous observations of sudden phase anomalies (SPA's) were made during some 30 solar flares. The observations indicate that during a solar flare the mean change of reflection height on a sunlit path is related in magnitude to the mean of the solar zenith angle along that path. Different flares, however, produce different curves of change of mean reflection height versus mean solar zenith angle. This can be explained in terms of the energy and intensity of the x rays producing the new reflecting region, permitting deduction of energy flux and effective wavelength of the incident x rays in some cases.

It is expected that SPA observations, when interpreted in this way, will provide a useful alternative to the present method of classifying solar flares in terms of brightness and area.

Effects of a Solar Eclipse on the D Region. The effects of solar radiation on ionization were investigated by means of VLF signals received and recorded during the solar eclipse of 20 July 1963. Some of the signals recorded were reflected from totally, or almost totally, eclipsed points in the *D* region of the ionosphere. The observations indicate that the response of the *D* region to ionizing radiation was between 10 and 100 times faster than indicated by earlier measurements of the effects of solar flares.

Independent experimental evidence has indicated that the *D*-region ionization is produced by two types of solar radiation: (1) the extreme ultraviolet radiation known as Lyman-alpha which comes from the visible disk of the sun, and (2) x rays which come from regions above active areas on the visible surface. The results of the eclipse experiment are consistent with this evidence and indicate that the ionizing radiation does not necessarily reach a minimum at the time of maximum optical eclipse, but may show variations associated with the locations of the active x-ray-producing regions.

Effects of a Solar Eclipse in the F Region. Vertical incidence radio soundings obtained at 22 locations across North America during the total eclipse of 20 July 1963 form the most extensive set of ionospheric observations ever made during a solar eclipse. Analysis of the data showed a well-marked and consistent geographical pattern of variation of f_0F_2, the ordinary-wave critical frequency of the F_2 layer, with eclipse time. A series of maps of f_0F_2 for the North American area are being prepared for every 15 minutes during the course of the eclipse. These maps should provide a useful reference for testing theories of physical processes of the ionosphere.

Geomagnetic Pulsations in the 30 to 0.003 Hz Range. The Bureau's ultra-low-frequency group has the mission, at frequencies between 30 and 0.003 Hz, to observe the electromagnetic field environment, to seek its geophysical source, and to understand propagation from distant natural sources. New equipment includes a data-recording and analysis system for encoding ULF data on magnetic tape at an extremely slow (1 in./min) speed, for rapid analysis when played back as signals in the kilohertz range. Ten new stations were established for observations at the magnetic pole, along the auroral zone, at conjugate field points, at the equator, and along meridians.

Balloon-borne counters were used to record bremsstrahlung x rays at College, Alaska, in a study of the geomagnetic effects associated with 15 auroral zone precipitation events. The effects were interpreted by use of the derived total disturbance field variations and the line current electrojet triangulations. In many cases the rapid field fluctuations seemed to result from enhanced conductivity created by the particle precipitation into the region of the auroral electrojet.

The relationship of infrasonic pressure waves to ionospheric disturbances and geomagnetic activity was investigated briefly. The result supported the proposition that the auroral region is a source of infrasonic pressure waves, probably arising from joule heating by the varying ionospheric electrojet.

The unique amplitude modulation and polarization for a class of natural signals near 1 Hz was studied. The multiple elements of rising frequency structure resulted in amplitude beating and a change in apparent polarization of the locus of the magnetic flux density vector. Preliminary observations indicated that the emissions propagate along magnetic field lines.

Earth Conductivity Measurements. In measurements of ELF propagation in the ionosphere it is necessary to take into account the effect of the earth—its conductivity and the velocity of propagation through it. One way of determining its conductivity is with the use of signals originating naturally in lightning discharges. These signals, called atmospherics, are very short in duration and contain energy over a wide band of frequencies, extending from a few hertz to several megahertz.

The top of an electromagnetic wave front is tilted in the direction of propagation when observed near the surface of the earth. This tilt is proportional to the ratio of the horizontal to the vertical electric field in the direction of propagation and is a function of the effective ground conductivity at each frequency.

The conductivity of the earth was determined by recording atmospheric signals received at a horizontal dipole and those received at a vertical monopole. The amplitude and phase spectra were used to determine tilt and from it the earth's conductivity computed as a function of depth. The results of this work indicated that the conductivity was 2×10^{-2} mhos/meter from the surface to a depth of 25 meters. Between 25 and 50 meters, the conductivity increased to 10^{-1} mhos/meter, and then decreased to 10^{-3} mhos/meter below

Two-meter diameter antenna of 16,000 turns used for ultra-low-frequency studies. This includes observations of the electromagnetic field environment, seeking its geophysical source, and understanding propagation from distant natural sources. **(See page 202)**

50 meters. The maximum depth for determining conductivity under normal conditions by means of atmospherics is about 2,000 meters.

This technique can be employed with mobile recording units to determine variations in earth conductivity for large areas. In this way it can be used as an aid in prospecting, particularly in conjunction with seismic operations.

Magnetic Dip Coordinates. The use of "numerical mapping" in the preparation of the Bureau's monthly publication *Ionospheric Predictions* (previously called *Basic Radio Propagation Predictions*) was inaugurated in January 1963. In using this technique, contours of critical frequency, or maximum usable frequency, are derived from mathematical mapping functions fitted to the observed data. Recent research showed that the mapping accuracy can be substantially improved by the use of geomagnetic dip latitude, based on the dip angle of the earth's magnetic field, instead of geographic latitude. The use of magnetic dip latitude simplifies and makes more accurate the mathematical representation because the ionosphere is strongly controlled by the earth's magnetic field.

2.4.2. TROPOSPHERE AND SPACE TELECOMMUNICATIONS

Efficient use of the radio frequency spectrum is the aim of the CRPL program in troposphere and space telecommunications. Attaining this objective requires a basic understanding of radio wave propagation, noise, and interference. Also required is a basic understanding of the physics of the atmosphere and detailed understanding of telecommunication systems. Present emphasis is on the development of theoretical and semi-empirical prediction methods and their statistical comparison with samples of radio wave propagation and radio noise data; the resultant information is disseminated by various types of publications and reports on consultative type programs. For example, several members of the CRPL staff performed work in support of international technical groups, such as the Consultative Committee on International Radio (CCIR) and the International Scientific Radio Union (URSI).

Transmission Loss Prediction. Continuing work is directed to the development of formulas for estimating median transmission loss, long-term power fading, phase interference fading, and service probability for propagation over irregular terrain and through a turbulent stratified atmosphere. A recent completed report shows the theoretical diffraction loss over ridges, cliffs, and bluffs. The last two represent discontinuities in electrical ground constants as well as in the height of the surface of the earth.

Computer programs for propagation over idealized inhomogeneous and irregular terrain will provide estimates of transmission loss for a great variety of terrain situations. Criteria were developed for applying certain engineering approximations to the diffraction attenuation over a double knife edge, and methods for evaluating multidimensional Fresnel integrals were improved for calculating diffraction loss over many knife edges.

Studies of Antenna Response. The response of standard antennas to specified electromagnetic fields is being studied, as is the response of selected antennas to standard plane wave fields. The propagation of waves through a turbulent stratified atmosphere over irregular terrain at frequencies above 100 MHz can sometimes be described in terms of discrete plane waves. General engineering formulas for such cases were derived for calculating antenna beam orientation, polarization, and multipath coupling loss.

Diffraction at Convex Surfaces. The theoretical solutions for diffraction in parabolic and circular cylinders were extended to obtain general engineering expressions which can be applied usefully to convex surfaces encountered in rough terrain. A tabulation was prepared of the Wait and Fock formulations of the Airy functions that are encountered in the theory of diffraction by convex surfaces.

Radio Meteorology. The turbulence-related variation of the atmospheric refractive index, which is largely responsible for signal variations at VHF and higher frequencies, can now be readily studied with the microwave refractometer. The accuracy of this instrument is limited primarily by the cavity used to sample the atmosphere under study. The conventional microwave sampling cavity was evaluated, using water-flow and wind-tunnel methods in conjunction with field sampling on a meteorological tower. These studies showed the cavities to be aspect-sensitive and also velocity-sensitive at low wind speeds. A new cavity was developed which has improved spatial resolution and practically no aspect sensitivity.

Measurements at the NBS Gunbarrel Hill, Colo., field station indicate that the microwave refractometer can be used to study the flux of water vapor over short periods of time. A high correlation, for example, was found between the variability of refractivity and the variability of absolute humidity near the ground for time intervals up to about 20 minutes.

Wide variations in propagation frequently occur over microwave relay paths, due to fluctuations in the refractive index of the atmosphere and the radio wave absorption from rain. In a study of variability for the Army Signal Corps, extensive weather data were obtained along radio paths between Pikes Peak and Gunbarrel Hill, and between Cheyenne Mountain and Karval, Colo. Detailed information on surface layer effects was obtained at the Gunbarrel Hill meteorological tower, and airborne measurements of refractivity were made several times daily along the entire radio path.

Mathematically tractable models of the absorptive properties of the atmosphere are very useful in solving certain kinds of radio propagation problems. A bi-exponential model of atmospheric water and oxygen absorption coefficients as a function of height was developed for frequencies between 6 and 45 GHz and scale heights were determined for representative profiles. It was found that large deviations from the temperature model were nearly undetectable in changes of the brightness temperature if the water vapor density was assumed to remain constant, but that small errors in estimating the absorption coefficients would result in large errors in the computed kinetic temperature. More accurate determinations of the line widths of

This radio-noise recording station at Ibadan, Nigeria, is one of a worldwide network of noise recording stations. Radio noise data and prediction services assist the telecommunications engineer in the design of facilities that promote the best utilization of the electromagnetic spectrum. **(See page 208)**

oxygen at low pressures also were made during the year. A useful formula for the scale height of oxygen absorption between 6 and 45 GHz was derived in terms of surface temperature and the average atmospheric temperature gradient.

Knife-Edge Diffraction Studies. During the past year propagation studies using 4,300-meter-high Pikes Peak as a diffracting knife-edge were continued with terminals for the path 223 km apart at Pueblo, Colo., and at the NBS Table Mesa field site. Continuous wave transmissions were used in the experiments. Horizontal and vertical space diversity at 751 MHz were studied. High correlation coefficients between the signal envelopes were found for two antennas spaced vertically by 20 to 30 wavelengths, but coefficients close to zero were obtained with horizontal spacing of 250 wavelengths. Severe fading was observed at 9.2 GHz; at some times the field strength variations within an hour had an approximate range of 40 dB. Observed overall median transmission loss values at 751 MHz agreed quite well with calculations based on a "rounded knife-edge" model, but a value calculated for the same model applied to 9.2 GHz was 13 dB greater than the measured value. This discrepancy may be due to different effective radii of curvature for the two frequencies, caused by terrain features on the summit of Pikes Peak.

Propagation Over Long Paths at SHF. Correlation between fading at two frequencies, 9293 and 9430 MHz, was measured over exactly identical long line-of-sight paths to investigate the effect of path geometry and meteorological conditions on the bandwidth of the medium. Meteorological data were obtained from measurements made at the surface and on an instrumented tower, radiosondes, radar, and an airborne refractometer. A 139-km path from Pikes Peak to Gun Barrel Mill, Colo., with a beam-elevation angle (from horizontal) of about 0.6°, was used in July and August, and a 113-km path from Cheyenne Mountain to Karval, Colo., with a beam-elevation angle of about 0.2°, was used in September. Both paths had a terrain clearance equivalent to several Fresnel zones.

Fading was more pronounced and the sample cross-correlation coefficient values generally less over the path with the smaller beam-elevation angle. This confirms the assumption that propagation over line-of-sight paths is more sensitive to the effects of horizontal stratification in the lower atmosphere when beam-elevation angles are small.

Surface-Satellite Communication Interference. In the event that space telecommunications services are assigned to frequencies shared with surface systems, such as point-to-point microwave systems, isolation between the systems must be provided. This could be provided by geographic separation and antenna discrimination.

Attenuation due to geographic separation can vary greatly with changes in propagation parameters. One of the ways in which the point-to-point microwave system can interefere with the space system is by scattering of its signal at storm cells in its path. This scattering effect can be predicted by correlation with weather radar data.

The effectiveness of antenna discrimination against unwanted signals is being investigated through both theory and measurement. Under study are possible decreases in the wanted signal due to beam or pattern orientation, polarization changes, or phase interference from multipath propagation. Statistical methods for describing the response of an antenna in an arbitrary orientation are being developed and measurements made using different frequencies and five different signal arrival directions.

Over-Water Transmission Loss Measurements. Characteristics of over-water paths were studied by making simultaneous radio transmission loss and meteorological measurements, in cooperation with the U.S. Air Force, on a 300-km path across a portion of the Gulf of Mexico. These measurements in a maritime temperate region show significant differences from the large pool of data available for a continental temperature climate, especially in the long-term variability of hourly median signals. A study was made of the correlation between various observable and predictable meteorological conditions and the corresponding transmission loss values.

Bandwidth of the Tropospheric Propagation Medium. The performance of transhorizon radio links using relatively large bandwidths is limited by intermodulation distortion caused by multiple scattering in the troposphere. A method of predicting the limiting bandwidth for a given tropospheric scatter path is being sought to replace the empirical methods on which present troposcatter-link design is largely based.

A measurement program, now completed under the sponsorship of the U.S. Air Force, was aimed at better understanding the relationship between observed intermodulation distortion and the path bandwidth measured in terms of the correlation between discrete components of the transmitted spectrum. The results, evaluated in terms of path length, antenna beam angles, modulation index, and carrier frequency, offer considerable insight into the general problem of bandwidth prediction. New approaches to the problem have been suggested as a result of this investigation.

Radio Noise Predictions. The basic objective of the CRPL radio noise studies is to furnish the telecommunications engineer with information on the interference environment relative to frequency, time, and location, so that design of terminal facilities will promote best utilization of the electromagnetic spectrum. To carry out this objective, the CCIR radio noise data were completely revised by NBS in a report, *World Distribution and Characteristics of Atmospheric Radio Noise.* At the request of CCIR the correction data were combined with the original predictions in a program to make the complete revision available for computer use.

Information now available will make possible more accurate predictions of not only average noise power, but also the expected deviation from the average power. Short-term variations of radio noise in the form of amplitude probability distributions can be predicted by the use of these two parameters.

Development of the practical method of predicting noise by use of more parameters makes possible more accurate predictions, supplanting the Gaussian noise model. The new prediction method has been applied, by means of a computer program, to determining error rates for several types of binary coded systems operating in the presence of atmospheric noise. One application was to the behavior of frequency-shift-keyed data transmission. This was extended to predict the reliability of the Minuteman radio launch control system operating in the presence of atmospheric radio noise.

Radio noise information is still being obtained, for future revisions of the noise predictions, by operation of a worldwide network of noise recording stations. The longer term measurements being obtained will be needed to determine the geographic dependence of the detailed structure of the noise.

Manmade Radio Noise and Transmission Loss Measurements. Levels of manmade radio noise at some of the Minuteman missile sites were checked by the CRPL mobile radio noise recorder to determine the degradation of the radio launch control system due to this noise and the relative importance of manmade and atmospheric radio noise. Signal and noise were compared by recording noise and a stable signal from a transmitter in the area simultaneously. By moving the mobile 500-watt transmitter, transmission loss measurements between sites and corresponding noise measurements were made. Not only transmission loss measurements, but also determinations of average ground conductivity were made, based on the transmission loss found. The effects of sky-wave interference, also, were studied at distances out to about 240 km.

Early morning preparations prior to the launching of an infrared spectrometer. The data from this instrument gave a water distribution profile of the atmosphere. Continuing efforts in this area will enlarge the knowledge and understanding of the absorption characteristics of the atmosphere. **(See page 209)**

Infrared Properties of the Atmosphere. A more thorough and exact understanding of the absorption characteristics of the atmosphere resulted from work on its infrared properties, supported by the Advanced Research Projects Agency. Theoretical studies of the behavior of water vapor and carbon dioxide in the infrared spectrum were analyzed in great detail and excellent agreement with controlled laboratory experiments obtained. Theoretical predictions can now be made with confidence. Continuing effort in this area will enlarge the knowledge available on other infrared spectral regions of the major atmospheric absorption constituents.

The experimental aspect of the program was successful in procuring valuable data on atmospheric absorption due to water vapor. A high-resolution grating vacuum spectrometer and a sunseeker were flown by balloon to an altitude of 30 km to record the solar spectrum and atmospheric absorption spectrum at a wavelength of 35 microns. These data, when analyzed, give a water distribution profile of the atmosphere. The Office of Naval Research provided financial support for the instrument flights, and the National Center for Atmospheric Research for the launch facilities.

Spectrum Analyzer. A data-reduction system for obtaining spectral information by investigating preselected frequency bands was developed for use in the data reduction facility. Signals to be analyzed are separated into their component frequencies of interest in a parallel array of active bandpass filters. Outputs of the filters are individually squared and averaged and then recorded on a multichannel strip chart recorder. Running records of the average power in up to eight frequency bands can be made simultaneously on one chart in the range of 1 to 10,000 Hz. Center frequencies and Q of individual bandpass filters are adjustable. The system is particularly useful for analyzing data with relatively smooth spectra, where information about the response details of corner frequency and order of rolloff is desired.

Tracking Accuracy Research. During the past year an extensive research program was conducted, under sponsorship of the U.S. Air Force, to determine the limitations due to atmospheric turbulence on microwave tracking systems. A series of experiments was performed on the island of Maui, Hawaii, using Mt. Haleakala to simulate air-to-ground paths. Various baseline configurations up to 1700 meters in length were used over 25-km paths. Ranges and range differences were studied over periods of time up to 7 days. Surface measurements of atmospheric conditions were made during radio observations to be examined for utility as predictors of radio conditions. Aircraft measurements of radio refractive index were made during part of the experiments, as well as range measurements using commercial microwave and optical geodetic instruments.

2.4.3. RADIO SYSTEMS

The Bureau's radio systems program provides technical information on radio propagation factors affecting design and use of radio systems. The emphasis of this work is on long-range radio transmission problems, and methods of measurement, for radio communication, navigation, timing, detection, and positioning systems. Radio wave propagation studies are carried out for ionospheric, groundwave, and line-of-sight paths to define the limitations, disturbances, and capacity of the transmission medium as a communication channel. The work is directed toward guidance of engineering practices, allocation and use of radio frequencies, and evaluation of system capabilities and limitations. The information is provided to meet the needs of Federal agencies and industry involved in radio telecommunication operation and regulation. Studies of information theory and coding, modulation, and antenna design are directed toward improvement of the reliability of systems and to the efficient utilization of the radio-frequency spectrum. Consulting and advisory work is done in accordance with the needs of other Government, commercial, and scientific agencies.

Radio-Frequency Propagation Determination and Prediction System. CRPL is the principal laboratory for development of a radio-frequency propagation determination and prediction system for the Navy

Bureau of Ships. The objective of the program is to increase naval high-frequency communication capability and high-frequency spectrum utilization as far as possible by assignment of optimum operating frequencies and warning of expected ionospheric disturbances.

The frequency selection problems peculiar to the Navy, and techniques for determining propagation and interference conditions were studied to provide information for the development of a system concept. Restrictions on system design imposed by operating procedures and interface requirements with other systems were investigated to establish the limits for the initial concept.

The system is expected to automate the selection of frequency assignments and usage within the Navy by means of techniques for assigning the operating frequency of any communication circuit on a short time basis. Techniques for monitoring existing propagation conditions, providing short-term (up to a few hours) predictions of expected conditions, and monitoring interference and noise in the frequency channel will be incorporated.

Studies are also being carried out on means of improving ionospheric disturbance warning capabilities and of using disturbance warning information in the naval system.

High-Frequency Ionospheric Radar. HF radar studies of ionospheric irregularities were continued, supported in part by the Rome Air Development Center, with several improvements in the instrumentation. One of these was the conversion from a 500 rev/sec azimuth scan of the antenna, at the Table Mesa field site, to a steerable-beam broadside array. This array consists of 25 log periodic antennas forming a steerable beam for additional flexibility in propagation studies. Operable between frequencies of 12 and 25 MHz and oriented toward 114° E of N, it was used on a 12-hour-per-day schedule during several days of November and December 1963 at a frequency of 17.6 MHz.

Ionospheric irregularities shown by backscatter records appeared mostly to be in the form of long fronts moving perpendicularly to their long dimension. Practically all motion seemed to have a southerly component, with most irregularities moving in a generally southeast direction. Mean speeds of about 600 km/hr were deduced. The irregularities give some indication of changing direction or orientation during their transit across the scanning beam. Some appear to be long curved fronts instead of linear ones; curvature might be expected for irregularities close to a generating source.

Ray tracings were made of models of ionospheric irregularities for better understanding of the relationship between ionospheric configurations and the forms observed in backscattered signals. From studies thus far it appears that modification of ionization densities of the order of 10 to 20 percent over relatively small distances (a few tens of kilometers) is sufficient to provide considerable focusing of backscattered signals. It also appears that irregularities in electron density are most effective at ionospheric heights slightly below the reflection level in the ray path.

Fading studies of backscattered signals indicated that for *F* region backscattered propagation most of the amplitude power spectrum appears below about 1 Hz and for *E* region below about 0.5 Hz. High speed motion of irregularities can increase values of the *F* region-propagated fading spectrum components. The high-frequency backscatter radar studies are supported in part by the U.S. Air Force.

Further plans were formulated for construction of an HF radar facility having an average power rating of 2 megawatts. The facility is being designed to be usable in a variety of experiments on HF propagation and ionospheric physics. Initially, it will be used to continue and expand radar studies which are now under way.

Modulation Research. The characteristics of propagation media as electrical networks or channels, and their relationship to system performance is being studied in the modulation research program. Various classes of modulation and demodulation techniques are studied in work directed toward improvement of performance on time-varying dispersive channels.

An experimental program to obtain *digital error distributions* and their relationship to propagation conditions on a high-frequency communication link was continued. The objective is to obtain data for optimum performance design of error-detecting and error-correcting codes for such links. The error distributions are valuable also in the design of adaptive modulation and coding systems. The received digital sequences are being analyzed to determine the average error rate, the distribution of the spacings between errors, and the autocorrelation function of the error pattern. In addition,

Directing a laser beam from Table Mountain (Boulder) toward Pikes Peak to determine beam fluctuations at long distances. The results of this program should indicate the limitations imposed by the atmosphere on the use of lasers for telecommunications. **(See page 216)**

the distribution of the number of errors for various work lengths will be determined. The first experiments used noncoherent frequency-shift keying. Plans were formulated to investigate the effects of other modulation techniques, such as differentially-coherent phase-shift keying, and to obtain more data for frequency-shift keying.

Theoretical studies of the performance of *digital communications* systems included the computation of error probabilities. Digital errors were computed as functions of average signal-to-noise ratio for various modulation and demodulation techniques and statistical signal-fading models, for both Gaussian and atmospheric additive noise. The use of a flexible Gamma-fading model made it possible to represent a wide range of realistic fading conditions. With moderate or severe fading conditions, the probabilities of error are nearly the same for both atmospheric noise and Gaussian noise; for weak fading the probabilities of error can differ considerably between the two noise conditions.

Theoretical studies of *error-detecting* and *error-correcting codes* in digital communication systems have continued. Simpler decoding procedures were sought, since the implementation difficulties of most codes seem to be related to decoding. A simple decoding procedure was devised for the large family of cyclic codes. A study was partially completed to arrive at a realistic comparison between the existing systems and higher performance alternatives. Operation was detailed to an extent including the intricacies of feedback control, synchronization, matching to teletypewriters, buffer storage, and other practical features.

HF Channel Characterization. Signal distortion and digital errors beyond the effects of additive noise are introduced by randomly-time-varying amplitude and dispersion characteristics of propagation over HF ionospheric links. The Bureau is studying the amplitude and phase correlation of received signals, in work for the U.S. Navy, as a function of time and frequency separation, using a large number of coherently generated signals. Such statistical characterizations will be made for various distance and geographic classes of HF communication paths likely to have unique characteristics.

Multipath Microwave Transmission. Experimental microwave measurements were made between a mountaintop and several lower-elevation receiving sites to determine the information rate or bandwidth limitations imposed by the atmosphere on satellite-to-earth communication systems at low elevation angles. This work is supported by the United States Air Force. A transmitter on Cheyenne Mountain near Colorado Springs, Colo., transmitted one-nanosecond pulses at 10 GHz for the transit-time resolution of path-length differences greater than 0.5 meter. Four lower-elevation receiving sites provided propagation path elevation angles of 9.5°, 3.4°, 2.0°, 0.6°, used in determining the dependence of multipath propagation on path elevation angle. Nearly 700 hours of measurements were made over the four paths over an eight-month period, during which no time-separated multipath propagation was observed. Some pulse fading observed on the two lowest-angle paths was caused by interference between multipath components and had propagation time differentials of a small fraction of a nanosecond. During all of the measurement time the bandwidth of the atmospheric medium, defined as the reciprocal of the propagation time differential, was greater than several GHz. These results were obtained at altitudes above 1.5 km in a relatively dry climate. It is planned to continue the measurements for another four months to complete a year of observations.

Antenna Measurements and Research. Methods of determining antenna gain by measuring the transmission loss were extended, removing the requirement for two identical antennas. A new technique is useful for measurement of three or more antennas, which do not have to be identical or have equal gains. The accuracy of final results can be estimated by comparing values obtained by pairing antennas in different combinations. Measurements on several standard gain antennas, used for calibration of commercial antennas, gave results which were within 0.2 dB of each other.

Experiments were carried out on the use of *slant-range* techniques for gain measurements and very promising results obtained. In these the antenna being tested is raised well above ground, while the target transmitter antenna is very close to the ground. The target transmitter antenna is positioned in such a way as to assure that its ground reflection does not illuminate the antenna being measured. The objective of this program is to develop improved techniques and instrumentation for the measurements of antenna gain, radiation pattern, impedance and other characteristics.

Antenna Aperture Synthesis. The principles of antenna aperture synthesis were applied in the past to field strength measurements to resolve the field into several components differing in directions of arrival, polarization, and phase. The field is probed over an area to simulate the effects of aperture antennas. The methods of solution are readily applicable to linear scans, and during the past year were extended to apply to circular scans. Circular scanning makes the technique more suitable for electromagnetic field sampling under practical conditions in the field. This work is supported by the U.S. Air Force in connection with a study of methods for measurement and analysis of complex radio frequency fields.

Frequency Utilization. Methods for predicting the performance of high-frequency sky-wave radio systems were improved by better statistical descriptions of propagation variations and the competing noise levels. Improved frequency utilization is made possible by better predictions of radio system performance obtained by use of electronic computers.

Electronic computers were routinely used to improve Voice of America international broadcast performance and to obtain optimum frequency utilization in the NASA ground communication system. Computers made possible improved prediction methods for planning data collection from a worldwide network of ocean buoys and revising frequency allocations. Electronic computers were used also in estimating the extended range of HF communications during the Appollo mission and in maintaining ground communications during mapping by the use of satellites.

Raising antenna at the South Pole Station for the detection of solar proton events by VHF forward scatter observations. This program is a cooperative effort by U.S., British, and Russian scientists. **(See page 217)**

Radiodetermination. The development of new techniques for more precise determination of position and the transfer of time standards is a continuing program of the CRPL radiodetermination section, sponsored by the U.S. Coast Guard. The Loran-C navigation system (using 100-kHz pulses) has been used in these studies for several years. A new study using the Loran-C signals was initiated during the past year to measure the dispersion of the groundwave pulse to determine the proper phase correction for propagation path. Dispersion represents dependence of velocity on wavelength and is an important effect for a high resolution system using wide-band pulses.

Predictable system accuracy is usually limited by knowledge of the effective conductivity of mixed paths. This limitation can be reduced by extracting the dispersion information from the distortion of the pulse shape. For transmission paths with intervening land, it is estimated that the error in position prediction might be reduced by a factor of 10 by use of the dispersion correction.

A technique for the transfer of time by means of VLF CW signals is being explored in cooperation with the Radio Standards Laboratory, using the Fort Collins WWVL transmissions at 20 kHz. Two closely spaced signals are transmitted in a given time-phase relationship and the time-phase relationship is observed at a distant receiver with respect to Loran-C time references. Experimental receiving equipment is under development and it is anticipated that field measurements will be started in January 1965. In these measurements, Loran-C will be used as a time base and the phase variations of the VLF signals will be measured relative to that base.

Applied Electromagnetic Theory. Theoretical studies supplementing experimental investigation of long-wave propagation have been carried out under the sponsorship of NBS and defense agencies. These studies have been principally directed toward greater understanding of the effects of the anistropy of the ionosphere and of ions on long-wave propagation.

The complete solution of the problem of low-frequency propagation between the earth and the ionosphere for an idealized model can be written as a series of integrals. The integrals are called wave hops because they reduce, in the saddle point approximation, to the ray hops of geometric optics. Unfortunately, the approximation is inadequate near grazing incidence and in the shadow region. A computer program was prepared to find the electromagnetic field in these regions by evaluating the wave hop integrals numerically for anisotropic models of the ionosphere. It is believed that the wave hop theory can be extended to allow variation with distance of ionospheric height and other parameters.

Classical magneto-ionic theory takes into account propagation in a pure electron gas, including the effects of collisions with neutral particles. The solution for propagation in a plasma with four constituents—electrons, positive and negative ions, and neutrals, including the effects of all twelve collision types—was reduced to a Booker-type quartic equation with modified coefficients. Given the coefficients of the quartic, the reflection from, and transmission through, a stratified ion-electron plasma can be calculated in the conventional way; a computer program was written to do this.

Laser Atmospheric Transmission Studies. The objective of this program was to investigate the propagation of coherent optical radiation through the earth's atmosphere and, in particular, the limitations imposed by the medium on the use of this portion of the electromagnetic spectrum for telecommunication. During the year several measurements were made of the effects of atmospheric turbulence on a tightly collimated laser beam operated CW at a wavelength of 0.6328 microns. Over a 15-km path the beamspread was about 0.5 m and over a 144 km path between the Table Mesa field site and the top of Pikes Peak the beam spread to about 9 m.

Amplitude fluctuations varying in frequency from a fraction of a hertz to several hundred hertz were observed on a single photocell placed in the beam. Longer term variations over periods of seconds to hours, in which the beam shifted location over an area several times its diameter, were also observed. Measurements of this type will be continued under varying conditions of atmospheric stability.

Infrasonics Research. Terrestrial atmospheric pressure variations propagated at sonic velocities in the frequency range 10^{-3} to 1 Hz are being studied in the infrasonics program. Observations are being made at four sites near Boulder and correlated with similar observations made by the NBS infrasonics group in the Washington, D.C., area. It is known that on many occasions infrasonic fluctuations occur at times of major ionospheric disturbances. Sources producing these events include severe earthquakes, major volcanic action, and severe weather fronts producing tornadoes. Other sources are long-lasting fixed events occuring only from September to March and centered in the Pacific Northwest area (and during the Southern Hemisphere summer in regions near the South American Anomaly), and events associated with particle influx in the auroral zone producing ionospheric disturbances. Most of the infrasonic events observed fall into one of the above categories with a fair degree of certainty.

The objective of this program is to investigate relationships, study mechanisms, and determine if a correlation between infrasonic waves and perturbations in radio waves exists. The project is related to the high altitude nuclear detection and high frequency radar programs.

Solar Proton Event Detection. During the past year terminals were set up in the Arctic and Antarctic for a number of radio paths in experiments on detection of solar proton events by VHF forward scatter observations. The Antarctic paths include stations at Byrd, the South Pole, McMurdo, Halley Bay, and Vostock. One of these is a British and another a Russian station; the U.S. stations are supported primarily by the National Science Foundation. The Arctic stations are at Frobisher Bay and Great Whale in Canada and Barrow, Anchorage, Annette Island, and Fairbanks in Alaska; this work is supported by the National Aeronautics and Space Administration. All of the stations except in Alaska are operated by the Bartol Research Foundation.

The two detection networks are using a frequency of about 23 MHz in the ionospheric *D*-region forward scatter mode of propagation. The frequency is lower than ordinarily associated with ionospheric forward scatter; it is being used to provide greater sensitivity during the low portion of the sunspot cycle. A byproduct expected from this operation will be information on the incidence of sporadic *E* at high latitudes.

2.4.4. UPPER ATMOSPHERE AND SPACE PHYSICS

A variety of approaches is being used in seeking to understand the propagation of radio waves through the atmospheric medium. CRPL is accumulating the basic information needed to use the medium most effectively. Methods used include theoretical study, laboratory simulation, ground-based geophysical observation, and satellite observation.

Theoretical and Analytical Atmospheric Studies. A quantitative investigation of ionization produced in the lower ionosphere by solar protons has been started. The aim of the investigation is twofold: first, to compare the calculations and observations of radio-wave absorption during polar-cap absorption events, and second, to seek ways of measuring solar proton fluxes and spectra by purely ground-based techniques. The former should provide important information on the properties of the lowest regions of the ionosphere. The latter provides information for monitoring and, it is hoped, forecasting conditions in the near-space environment. Preliminary calculations indicate that measurements of radio-wave absorption at very high geomagnetic latitudes can provide a reasonably accurate estimate of the flux of solar protons with energy above about 5 MeV.

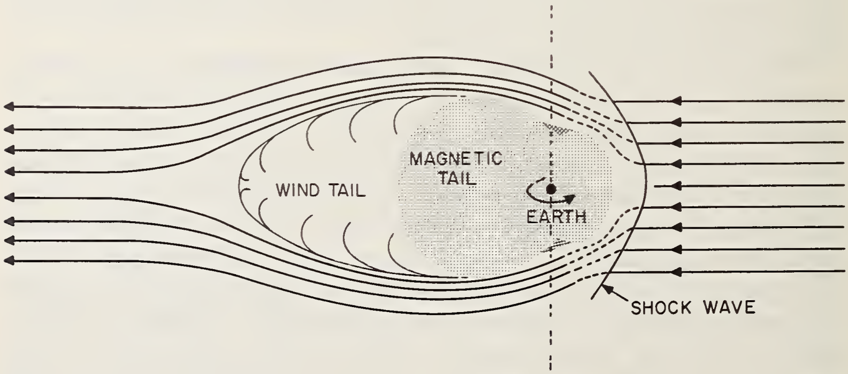
The propagation of solar protons from the sun to the earth was investigated theoretically using a model in which the initial rise of proton flux at the earth is controlled by diffusion of the protons through a thin region of the solar atmosphere. Good agreement was found in comparing theoretical results with observations of solar protons by the satellite *Explorer XII* beyond the geomagnetic field, allowing a determination of diffusion coefficient for energetic protons in the solar atmosphere.

Computations of the theoretical shape of the outer boundary of the magnetosphere were completed. The results indicate boundary shapes and magnetic field disturbances which are in agreemnt with data reported from satellites. The magnetic field disturbances are of a magnitude to justify their inclusion as part of magnetic storm variations.

Atmospheric Collision Processes. The analysis of many processes occuring in the upper atmosphere requires an accurate knowledge of the momentum transfer cross section between low-energy electrons and atmospheric gases. The resonance absorption of microwave energy by a slightly ionized gas in a magnetic field can be analyzed to yield this quantity. The work done thus far includes an investigation of the effects on the shape of the cyclotron resonance line of varied electron energy and the energy dependence of the collision frequency between electrons and the background scattering particles. These calculations included resonance line shapes which might be obtained in practicc from experimentally determined collision frequencies for helium, argon, oxygen, and nitrogen. The change in broadening produced by very small concentrations of ions was computed.

The calculations of the present work show that the shape of the cyclotron resonance line is strongly affected by the energy dependence of the collision frequency and the distribution of electron energies. The line shape is in general less sensitive to realistic changes in energy distribution than to changes in the velocity dependence of the collision frequency.

The line shape may be sensitive to small variations in the collision frequency-energy relationship when it is a strong relationship. Complicated



Solar wind distortion of the geomagnetic field boundary. Such studies provide better understanding of magnetic storm variations. **(See page 217)**

dependences can then often result in line shapes which are more Lorentzian than would be calculated from an approximation to the dependence. Therefore the scientist must know the energy dependence of a collision frequency in order to obtain accurate average values for it from cyclotron resonance measurements. It was concluded from the calculations that accurate results for collision cross sections can be obtained from cyclotron resonance techniques only if detailed analysis is used in interpreting experimental data.

Gas Discharge Afterglow. A program of gas discharge afterglow experiments was instituted to study the reaction processes of electrons, ions, and unstable species at low thermal energies. The dependence of emission intensities on electron temperature indicated that recombination of molecular ions is not likely to be a significant afterglow process in helium, in conditions under which it was previously assumed to dominate. Experimental reports of dissociative recombination in helium were explained satisfactorily as three-body recombination involving two electrons and either the atomic or molecular ion.

Infrared Absorption by Charge Transfer. Infrared spectroscopy of weak charge-transfer complexes led to formulation of new mechanisms and selection rules relating spectroscopic observations to molecular structure. The infrared absorption of an acceptor molecule vibrating in a complex group was shown to be due to the variation of the molecule's vertical electron affinity during vibration. Thus the intensity of a vibration band can be related to the slope of the molecular negative ion potential curve at the molecular equilibrium internuclear distance. Nitric oxide in a solid krypton matrix was shown to be capable of absorbing radiation by the charge-transfer processes postulated. Other small molecules and perhaps even atoms may be able to absorb radiation, when in condensed phases, by this mechanism.

Jicamarca Radar Observatory. At the Jicamarca Radar Observatory, located on the magnetic equator near Lima, Peru, studies are being made of various features of the equatorial ionosphere with a powerful radar at 50 MHz. Its basic function is to study the distribution of electron density for heights up to 10,000 km by means of the incoherent scatter technique. Other parameters of the ionosphere, such as electron and ion temperatures, are also being measured.

The Jicamarca radar has been operating at full capability in incoherent scatter studies since December 1962. Observations since that time have been largely devoted to testing certain aspects of the incoherent scatter theory and to refining the accuracy of measurement techniques.

Electron Density and Ionospheric Constituents. The incoherent scatter theory predicts that radar can be used as a mass spectrometer to identify the ionized constituents of the upper atmosphere, but a series of attempts to observe this effect at Jicamarca was unsuccessful. This led to the discovery by theoreticians that the interaction of the ions themselves renders the effect essentially unobservable under most conditions. As a consequence, the Jicamarca group faced uncertainty in electron density measurements at heights where more than one kind of ion exists in significant quantities.

The difficulty was solved by instrumenting the radar to measure electron density profiles by use of the Faraday effect. Profiles obtained by this technique are not subject to ambiguity due to ion mixtures, or to varying electron/ion temperature ratio (Te/Ti). However, comparison of simultaneous profile measurements by the radar and by the *Alouette* topside sounder satellite (S–27) disclosed inaccuracies in measurements by one or both means.

Most of the errors were corrected in recent radar observations, and the radar measurements now show excellent internal consistency. The observations yield information not only on electron density, at heights from 200 to approximately 10,000 km, but also on electron and ion composition and temperature at heights from 200 to 1,200 km. Protons were found to be the major ionic constituent in the magnetosphere, outnumbering atomic oxygen atoms at some heights and certain times of day. Ion temperatures ranged from 800 to 1500 °K, with the higher temperatures occurring at greater heights. As the observations continue, it will be possible to distinguish whether helium occurs above Jicamarca in significant concentrations.

Synchrotron Radio Noise Measurements at Jicamarca. Observations of the decay of the synchrotron radio noise created by the July 9, 1962 nuclear explosion were being continued at Jicamarca. Continuous observation with a riometer at 30 MHz revealed a decay rate having a time constant T (in the amplitude proportionality expression $1/(1+T)$) of approximately 40 days. The noise still present two years after the explosion is largely indistinguishable from the sky background with this equipment, but at 50 MHz the synchrotron radiation can be distinguished by its linear polarization from the random polarization of the sky background. Synchroton noise measurements at this frequency show a decay time constant of 50 to 60 days but should continue to be measurable for several more years.

Plasma Instability Research at Jicamarca. Radar measurements combined with theoretical studies at Jicamarca show that acoustic-wave plasma instabilities are generated in the equatorial E region by the flow of the strong equatorial electrojet. These instabilities give rise to ionospheric wave irregularities which are primarily alined with wave fronts parallel to the lines of force of the earth's magnetic field. The strong radar echoes from these irregularities bear characteristics typical of auroral radar echoes. The Jicamarca group believes that auroral radar returns arise from essentially the same phenomenon. Recent spectrum observations of the radar echoes at Jicamarca suggest that the irregularities are generated by several distinct modes of plasma instability, only one of which is thus far accurately explained by theory. The new spectrum observations were made, with greater accuracy than previously possible, by use of computing equipment assembled for the incoherent scatter observations.

Ionospheric Absorption at Conjugate Points. Since early 1963 a program of geophysical studies has been in progress at pairs of stations

The 22-acre antenna of the Jicamarca Radar Observatory near Lima, Peru. This radar, in full operation since December 1962, has recently been re-instrumented to measure electron density profiles using the Faraday effect. These instruments also provided information on electron and ion composition and temperatures from 200 to 1200 km. **(See page 219)**

situated at opposite ends of selected lines of the earth's magnetic field. The new information provided by these continuing studies will add considerably to our knowledge of auroral phenomena and the effects of energetic particles at high latitude. Three such magnetically-conjugate pairs are in use, one in the auroral zones and, one at subauroral latitudes, and the other at the polar caps. The three northern stations are in Canada (by arrangement with various departments of the Canadian government) and the three southern stations are maintained by the U.S. Antarctic Research Program.

The program includes the study of ionospheric absorption, measured with riometers. The analysis completed thus far shows that the absorption is broadly similar at conjugate points, but that there are also certain differences. One point of similarity shows that fluctuations in the daytime absorption (for periods of several minutes) are closely in phase at the conjugate points. On the other hand, nighttime absorption often includes a slowly varying antiphase component.

Airglow Arcs in the Tropics. Optical radiation at a wavelength of 6300 Å is emitted from the upper atmosphere over the entire earth, due to the oxygen atom. In the auroral zone, it is a prominent feature, giving a reddish color to the upper part of many active auroral displays. In mid-latitudes it is the principal spectroscopic feature of the so-called *M*-arcs, which occur especially during the sunspot maximum.

Another manifestation of the emission has been under study for several years in the tropics, between the geomagnetic latitudes of about $+20°$ and $-20°$. The emission undergoes sporadic increases of intensity (as much as ten times normal intensity, still well below visibility) over periods of one to two hours. Studies of the entire sky indicate that the increase covers a significant geographical region and often is oriented along magnetic parallels approximately in an arc. Of particular interest is the fact that the increase in optical radiation is directly correlated with a concurrent lowering of the F layer and an increase in its electron density. The phenomenon seems to be associated with the drift of ionization from high above the magnetic equator down along the magnetic lines of force to the F region over latitudes of 15 to 20°.

Model of Natural Sodium Abundance. The emission of the sodium resonance doublet at 5890 and 5896 Å from the upper atmosphere during twilight is of considerable interest not only because it comes mainly from the D region of the ionosphere, but also because this emission mechanism is one that is well understood. There is no doubt that the emission process is resonant scattering of sunlight. Observations of the intensity of this emission can be directly related to the concentration of free atomic sodium in the atmosphere.

Recent observations from several sites at latitudes from 65°N to 45°S were assembled in a model of the atmospheric distribution of sodium. This model considers both the chemical and ionic equilibria of sodium; its recombination coefficient for ionized sodium of 4×10^{-7} cm ^{3} sec^{-1} reproduced, reasonably satisfactorily, the observed seasonal and diurnal changes in sodium abundance. The first tentative numerical solution exhibited agreement with the observations. The recombination coefficient applied to ionized lithium gives realistic results in this case also.

During the development of the model, it became obvious that account must be taken of the pole-to-pole circulation of the atmosphere at D-region heights. This circulation is clearly shown in the well-known "meteor wind" measurements and is confirmed by the observations of lithium originating in some thermonuclear explosions. Calculations are in progress to improve the sodium model by using the observed wind velocities and numerically integrating the chemi-ionic reaction equations.

Ionospheric Studies by Reception of Satellite Signal. CRPL scientists used signals from the satellite S–66 to chart the electron distribution below the satellite path. The electron density was found by determining the signal polarities, and thereby the Faraday rotation imposed during transit on the linearly polarized satellite transmissions at two closely spaced frequencies. Especially designed antennas, receivers, and recording devices were used at three receiving stations. The data must be recorded and analyzed together to obtain values for the electron densities; the values can then be plotted on geographic charts.

Analysis of the data required comparison of recordings from three stations, located about 50 miles apart along a line parallel to the satellite's path. The data at two of the stations are transmitted to the principal observing station at Table Mountain, Colo., over telephone lines, to simplify obtaining accuracy in recording and time notation. This made it practical to operate the two remote stations unattended; in design they are fully transistorized, battery powered, and controlled from the Table Mountain station by signals transmitted over the same lines as the data. Bottle-gas-powered thermoelectric converters will be added to keep the batteries charged and permit unattended operation for long periods of time.

The slow rate of Faraday rotation at the two frequencies, near 40 and 41 MHz, makes it necessary to use a scanning form of polarimeter to determine the polarization plane at each frequency approximately once a second at each station. This is done with fixed dipole antennas, oriented in a cross and connected through a hybrid transformer to produce two orthogonal circular polarization components. The phase difference between these two equal-amplitude components is a function of the polarization orientation of the incoming waves. The rest of the receiver circuitry produces output signals similar to those produced by an input from a mechanically rotated dipole antenna. Built-in receiver circuitry permits insertion of synchronizing and calibration signals, including a test signal radiated from a small calibration antenna for a complete system check whenever desired. Two receivers are required at each station, one for each frequency, but the rest of the system is sufficiently broadband for a single sequence of stages to treat similarly the two close-spaced frequencies.

The signals from the main station at Table Mountain are demodulated and processed to produce oscilloscopic displays which are photographed simultaneously on continuously moving film. The audio-tone telemetry will be recorded on magnetic tape for permanent storage and further analysis if desired.

The output of the data analysis will be a map for each satellite pass of electron distribution in the plane containing the satellite path and the three ground stations. Two or three satellite passes per day are expected to produce records of quality sufficient for full analysis.

2.4.5. ELECTROMAGNETIC RESEARCH

A number of topics which can be generally classified as electromagnetic research were studied by the Consultant on Radio Wave Propagation. This work was supported by the Bureau, the Air Force Cambridge Research Laboratories, the Department of Defense Advanced Research Projects Agency, and the Navy BuShips in approximately equal amounts. Although the studies are seemingly unrelated, the methods used have much in common and some recent accomplishments are therefore reported together.

Mode Theory of the Propagation of VLF Radio Waves. The mode theory was subjected to new treatment to exploit the essential two-dimensional nature of wave propagation in the earth-ionosphere waveguide. It was shown that the usual working formulas of VLF mode theory can be derived directly from orthogonality considerations, without resorting to erudite arguments in the complex plane. Furthermore, the physical insight gained by this novel development immediately suggested how the formulas can be generalized to an earth-ionosphere waveguide of nonuniform width.

Influence of the Lower Ionosphere on Propagation of VLF Waves. Because of the great number of papers dealing with VLF radio propagation, there appeared to be a need for consolidation of some of the recent theoretical data. Toward this end, the expected values of the attenuation and phase velocity of the dominant modes in the frequency range from 8 to 30 kHz were expressed in convenient graphical form. The results included the effects of earth curvature, ground conductivity, and the gradient of the effective conductivity of the lower ionosphere.

Effect of Ionospheric Perturbations at VLF. The effect of ionospheric perturbations at VLF was calculated, taking into consideration many factors affecting propagation. It was first assumed that the earth's magnetic field could be neglected in treating the oblique reflections of radio waves from a continuously stratified ionized medium. The height profile of the effective conductivity was taken to be a Gaussian curve superimposed on the undisturbed exponential form. The reflection coefficient was shown to be influenced by the vertical location of the Gaussian perturbation, being increased in magnitude in some cases and decreased in other situations. In nearly all cases, insofar as phase was concerned, the presence of the perturbation corresponded to a lowering of the reflection height.

The same analytical method was also used to study the effect of a hyperbolic-type transition in which the effective conductivity is increased at all heights above a given level. These results, taken collectively, have application to the interpretation of VLF propagation data observed during solar flares, magnetic disturbances, and high-altitude nuclear detonations.

Reflection Coefficients for a Lossy Magnetoplasma. Extensive values were calculated for the reflection coefficient of a horizontally stratified ionized medium. The profiles of electron density and the collision frequencies were both taken to be exponential functions. The d-c magnetic field was restricted to be horizontal and transverse to the direction of propagation. The results were applied to the study of oblique reflection of VLF radio waves in the D layer of the ionosphere for propagation along the magnetic equator. It was confirmed that the reflection coefficient was nonreciprocal in both amplitude and phase. The magnitude of the reflection coefficient for a wide range of the parameters was greater for west-to-east propagation than for east-to-west propagation.

Diffraction Effects at VLF for a Localized Ionospheric Depression. The effect of a localized ionospheric depression, such as can result from an ionospheric disturbance, on the propagation of VLF waves in an earth-ionosphere waveguide was studied. The depressions in the upper boundary of the waveguide cause the waveguide to be nonuniform in the vertical dimension. Calculations were carried out for depressions resulting from approximately rectangular disturbances and for the more realistic disk and bowl-type depressions. The results confirm what was previously suspected, that perturbations lying off a great circle radio path can produce appreciable changes in the phase of the field at the receiver. The findings of this study have application to waveguide propagation when localized electrons are "dumped" from radiation belts or nuclear explosions.

D-Layer Characteristics Studied by VLF Propagation. One of the most challenging problems in VLF research is obtaining information on the ionospheric D layer from data on the amplitude and phase of the signal from a distant continuous wave transmitter. A previous approach has been by comparison of observed attenuation versus frequency data with theoretical curves calculated for various assumed models. A better approach is being used in the present study; measured data is inverted in such a way that the characteristics of the medium are found rather than assumed. Theoretical study has demonstrated that measured attenuation and phase data can be used to determine the effective wave impedance of the lower ionosphere. The consequences of this work, when completed, should be far-reaching in experimental studies of the D layer.

Microwave Models for VLF Propagation. CRPL, in collaboration with the University of Colorado, is investigating the use of microwave models as an analytical method for studying VLF radio propagation. The rectangular waveguide used has an inside thickness approximately equal, in wavelengths at 1 GHz, to the height of the ionosphere measured in wavelengths at 15 kHz. This being so, and since both waveguides have similar modal equations and perturbations in the walls of each similarly affect propagation, the microwave waveguide can be used, with suitable wall loading, to simulate the electrical characteristics of the ionosphere.

Experimental studies were made of propagation in the waveguide with several different wall perturbations. It was found that the wall perturbation causes the conversion of substantial amounts of energy from one of the propagating modes to others, as suggested by theory. It was found also that the effects of the perturbation are noticeable at great distances and that the amount of energy converted to various propagating modes is critically dependent upon the size and shape of the perturbation.

Impedance of a Monopole Antenna with a Radial-Wire Ground System. The impedance of a vertical monopole located over the surface of an imperfectly conducting earth and having a radial-wire ground system is an important parameter in designing low-frequency antennas. Extensive calculations (carried out in collaboration with the University of Colorado) based on previously developed theory show the antenna impedance to be a function of antenna height, top-loading, and number, size, and length of radial wires, as well as of ground conductivity and permittivity. Some of these calculations have been checked experimentally, using microwave-model techniques.

The Electromagnetic Field near a Wedge Apex. Numerical results for the structure of the field in the apex region of a wedge were obtained, using the exact series solution for diffraction by a perfectly conducting wedge. This provided insight into the nature of electromagnetic fields near a surface discontinuity. The results provided some justification for the use of approximate boundary conditions, which have been used previously in studying radio propagation over terrain features.

Oblique Propagation of Groundwaves Across a Coastline. In continuing its study of the propagation of groundwaves over inhomogeneities, the Bureau calculated the amplitude and phase changes of a groundwave passing obliquely over a flat-lying and a sloping coast. In the first case, for both land and sea assumed to be smooth, level, and homogeneous, it was shown that the wave reflected at the discontinuity depended critically on the angle of incidence, while the transmitted wave was only weakly dependent on it. The wave reflected at a beach sloping up with constant rise, on the other hand, can be quite significant and fundamentally different in character from a wave reflected at a flat-lying coastline.

The influence of a finite transition zone on the electrical characteristics at the land/sea boundary also has been studied in some detail. In general, it was found that the characteristics of the transition region will not produce significant modifications of the transmitted field. However, the magnitude of the reflected field for a flat-lying coast was greatly reduced as the width of the transition zone was increased beyond about one-quarter wavelength.

Waves in Cold Plasma. A way of representing the composite magnetic field resulting from a source and a nearby isotropic conducting cylinder, surrounded by concentric stratums of plasma and generating a d-c magnetic field alined with the cylindrical axis has been developed. Computation was facilitated by transforming the harmonic series representation to a more highly convergent form. The presence of the d-c magnetic field was found to destroy the azimuthal symmetry usual in configurations of this type. The situation is somewhat analagous to the propagation of radio waves in a spherical earth-ionosphere system.

Sources in Plasma. Radiation from a finite source in a compressible electron plasma was studied by means of a theoretical model, a perfectly conducting sphere excited uniformly by an annular slot. In this configuration Maxwell's equations were separable, permitting it to be shown that a portion of the total power supplied by the source was radiated as an acoustic wave in the electron fluid. The influence of a concentric dielectric coating on the sphere also was analyzed and found to have the effect of reducing the power "wasted" in electro-acoustic energy. The results have possible application to antennas for space vehicles. Related problems with various geometrical configurations also have been considered.

3. APPENDIXES

3.1. ORGANIZATION OF THE NATIONAL BUREAU OF STANDARDS*

The Bureau is headed by a Director who is appointed with the advice and consent of the Senate. The Director is assisted in the overall management of the Bureau by a Deputy Director. In addition, there are three Associate Directors and a Manager of the Boulder Laboratories who are responsible for the planning and operation of various technical and administrative management services in support of the Bureau's technical programs.

Technical program activities are conducted in four major organizational units known generally as Institutes. Each is headed by an Institute Director who is responsible for the development and direction of research programs and central national services essential to the fulfillment of a broad segment of the Bureau's mission. These major organizational units are:

(1) The Institute for Basic Standards, which includes 13 divisions (4 in Boulder, Colo.), each serving a classical subject matter area of science and engineering;

(2) The Institute for Materials Research, which consists of 7 divisions (1 in Boulder, Colo.), organized primarily by technical field;

(3) The Institute for Applied Technology, which includes 12 industry-oriented divisions; and

(4) The Central Radio Propagation Laboratory, which comprises a series of four divisions located at Boulder, Colo.

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*As of July 1, 1964.

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Technical Information Officer	J. R. Craddock
Library	L. E. Leonard

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R. D. Huntoon

ASSOCIATE DIRECTOR, MEASUREMENT SERVICES
W. A. Wildhack

ASSISTANT TO THE DIRECTOR
H. L. Mason

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Thermodynamics & Transport Data	E. R. Johnson
Chemical Kinetics	S. A. Rossmassler
Information Systems	F. L. Alt

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Consultants	H. Oser
	Mrs. Ida Rhodes
	W. J. Youden
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Computation	D. I. Mittleman
Statistical Engineering	J. M. Cameron
Mathematical Physics	W. H. Pell
Operation Research	A. J. Goldman

ELECTRICITY	
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Electrochemistry	W. J. Hamer
Electrical Instruments	F. L. Hermach
Magnetic Measurements	I. L. Cooter
Dielectrics	A. H. Scott
High Voltage	F. R. Kotter
Absolute Electrical Measurements	F. K. Harris
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Assistant Chief	D. B. Judd
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Refractometry	F. E. Washer
Photographic Research	C. S. McCamy
Length	T. R. Young
Engineering Metrology	I. H. Fullmer
Mass and Volume	P. E. Pontius
MECHANICS	
Chief	B. L. Wilson
Consultants	J. M. Frankland
	E. C. Lloyd
Sound	R. K. Cook
Pressure and Vacuum	D. P. Johnson
Fluid Mechanics	G. B. Schubauer
Engineering Mechanics	L. K. Irwin
Rheology	R. S. Marvin
Combustion Controls	F. R. Caldwell
HEAT	
Chief	R. P. Hudson
Assistant Chief, Thermodynamics	C. W. Beckett
Temperature Physics	J. F. Swindells
Heat Measurements	D. C. Ginnings
Cryogenic Physics	E. Ambler
Equation of State	J. Hilsenrath
Statistical Physics	M. S. Green
ATOMIC PHYSICS	
Chief	K. G. Kessler
Physical Science Administrator	J. A. Suddeth
Spectroscopy	W. C. Martin, Jr.
Infrared and Microwave Spectroscopy	D. R. Lide, Jr.
Far Ultraviolet Physics	R. P. Madden
Solid State Physics	H. P. R. Frederikse
Electron Physics	J. A. Simpson
Atomic Physics	H. Boyne
Plasma Spectroscopy	W. L. Wiese
PHYSICAL CHEMISTRY	
Chief	M. B. Wallenstein
Consultants	W. L. Clinton
	E. J. Prosen
Chemical Kinetics Information Center	R. B. Parlin
Theoretical Chemistry	M. Krauss
Thermochemistry	D. D. Wagman
Surface Chemistry	R. Klein
Organic Chemistry	H. S. Isbell
Molecular Spectroscopy	D. E. Mann
Elementary Processes	R. E. Ferguson
Mass Spectrometry	H. M. Rosenstock
Photo Chemistry and Radiation Chemistry	J. R. McNesby

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Chief	L. M. BRANSCOMB

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Scientific Assistant	E. H. EISENHOWER
Radiation Theory	H. A. OLSEN
Radiological Physics	
Chief	J. W. MOTZ
X-ray Physics	J. W. MOTZ
Dosimetry	S. W. SMITH
X-ray Standards	H. O. WYCKOFF
Nuclear Physics	
Chief	H. W. KOCH
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Neutron Physics	R. S. CASWELL
Photonuclear Physics	E. G. FULLER
Nuclear Spectroscopy	R. W. HAYWARD
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Chief	J. E. LEISS
Accelerator Engineering	J. E. LEISS
Radiation Physics Instrumentation	L. COSTRELL
Accelerator Physics	J. E. LEISS

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Assistant Chief for Program Evaluation and Development	H. W. LANCE
Assistant Chief for Technical Planning and Coordination	E. C. WOLZIEN
Scientific Consultant	D. M. KERNS

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Assistant Chief	G. E. HUDSON
Consultant	P. F. WACKER
Assistant Chief for Technical Planning and Coordination	W. D. GORING
Frequency-Time Dissemination Research	A. H. MORGAN
Frequency-Time Broadcast Services	D. H. ANDREWS
Radio and Microwave Materials	J. L. DALKE
Atomic Frequency and Time Interval Standards	R. C. MOCKLER
Radio Plasma	K. B. PERSSON
Microwave Physics	R. ZIMMERER, *Acting*

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Assistant Chief for Technical Planning and Coordination	W. J. ANSON
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	M. C. SELBY
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Low Frequency Calibration Services	F. D. WEAVER, *Acting*
High Frequency Calibration Services	K. R. WENDT
High Frequency Electrical Standards	C. M. ALLRED
High Frequency Impedance Standards	R. C. POWELL
Microwave Calibration Services	R. E. LARSON
Microwave Circuit Standards	M. B. HALL

*Located at Boulder, Colo.

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Spectrochemical Analysis	B. F. Scribner
Electrochemical Analysis	R. G. Bates
Quantitative Separations	R. A. Paulson, *Acting*
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Consultant	J. I. Lauritzen, Jr.
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Consultant on Rubber	L. A. Wood
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Polymer Chemistry	L. A. Wall
Polymer Physics	E. Passaglia
Polymer Characterization	N. P. Bekkedahl
Dental Research	W. T. Sweeney
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Consultant on Math Statistics	J. Mandel
Consultant on Paper	J. L. Harvey, *Acting*
Consultant on Textiles	H. F. Schiefer
Product Evaluation and Testing	Vacant
Procurement Systems	Vacant
Evaluation Criteria	R. D. Stiehler
Performance Research	Vacant
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Assistant Chief	G. A. Ellinger
Special Assistant	H. C. Burnett
Consultant	L. Wyman
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Alloy Physics	L. H. Bennett
Lattice Defects and Microstructures	A. W. Ruff, Jr.
Corrosion	G. A. Ellinger
Metal Physics	R. E. Howard
Electrolysis and Metal Deposition	A. Brenner
Crystallization of Metals	R. L. Parker

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Consultants	G. Gordon
	E. R. Lippincott
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Glass	C. H. Hahner
High Temperature Chemistry	Vacant
Crystal Chemistry	H. S. Peiser
Physical Properties	J. B. Wachtman, Jr.
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Chief	C. O. Muehlhause

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Assistant Chief	R. J. Corruccini
Consultant	A. F. Schmidt
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Cryogenic Data Center	V. J. Johnson
Cryogenic Properties of Solids	R. H. Kropschot
Properties of Cryogenic Fluids	R. J. Corruccini
Cryogenic Systems	D. B. Chelton
Cryogenic Metrology	T. M. Flynn
Cryogenic Fluid Transport Processes	R. V. Smith

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DEPUTY DIRECTOR
J. P. Eberhard

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Technologist	L. S. Hardland
Research Assistant	Miss A. J. Kelly
Domestic Technology Information	E. A. Tietz
Aid Technology Information	Vacant

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OFFICE OF WEIGHTS AND MEASURES

Chief	M. W. Jensen

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Technical Standards Coordination	Miss J. Hartman

*Located at Boulder, Colo.

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Deputy Chief	W. W. Dunlop
Document Management	
Chief	P. W. Larson
Document Analysis and Services	
Chief	Miss L. A. Hamrick
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Chief	Vacant
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Heat Transfer	H. E. Robinson
Inorganic Building Materials	B. E. Foster
Metallic Building Materials	D. G. Moore
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Chief	Vacant
INFORMATION TECHNOLOGY	
Chief	S. N. Alexander
Technical Assistant	Miss M. R. Fox
Pilot	J. P. Nigro
Research Information Center	Miss M. E. Stevens
Components and Techniques	R. D. Elbourn
Computer Technology	J. A. Cunningham
Measurements Automation	R. T. Moore
Engineering Applications	J. P. Nigro
Systems Analysis	S. N. Alexander, *Acting*
PERFORMANCE TEST DEVELOPMENT	
Chief	Vacant
INSTRUMENTATION	
Chief	G. F. Montgomery
Engineering Electronics	G. Shapiro
Electron Devices	C. P. Marsden
Electronic Instrumentation	G. F. Montgomery, *Acting*
Mechanical Instruments	A. Wexler
Basic Instrumentation	J. Stern
TRANSPORT SYSTEMS	
Chief	S. M. Breuning
TEXTILES AND APPAREL TECHNOLOGY CENTER	
Chief	Vacant

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C. G. Little

DEPUTY DIRECTOR
J. W. Herbstreit

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	R. M. Gallet
	A. G. Jean
Chief CRPL Liaison and Program Development	A. H. Shapley
Consultant, Radio Wave Propagation	J. R. Wait

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Assistant Chief	T. N. Gautier
Assistant to Chief for Technical Planning and Coordination	J. A. Kemper
Consultants	L. R. Megill
	H. H. Howe
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Low Frequency and Very Low Frequency Research	D. D. Crombie
Ionosphere Research	K. Davies
Prediction Services	Mrs. M. Leftin
Sun-Earth Relationships	T. E. Van Zandt
Field Engineering	H. G. Sellery
Radio Warning Services	J. V. Lincoln
Vertical Soundings Research	J. W. Wright

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Consultant	D. M. Gates
Consultant, Terminal Equipment	E. F. Florman
Data Reduction Instrumentation	W. E. Johnson
Radio Noise	W. Q. Crichlow
Tropospheric Measurements	M. T. Decker
Tropospheric Analysis	P. L. Rice
Spectrum Utilization Research	A. P. Barsis
Radio Meteorology	B. R. Bean
Lower Atmosphere Physics	M. C. Thompson, Jr.

RADIO SYSTEMS	
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Assistant Chiefs	D. W. Patterson
	W. F. Utlaut
Consultant	G. W. Haydon
Applied Electromagnetic Theory	J. R. Johler
High Frequency and Very High Frequency Research	L. H. Tveten
Frequency Utilization	G. W. Haydon
Modulation Research	C. C. Watterson
Antenna Research	H. V. Cottony
Radiodetermination	G. Hefley

UPPER ATMOSPHERE AND SPACE PHYSICS	
Chief	E. K. Smith, Jr.
Assistant Chief	F. L. Taylor
Assistant to Chief for Technical Planning and Coordination	S. S. Barnes
Consultants	D. K. Bailey
	G. C. Reid
	R. J. Slutz
Upper Atmosphere and Plasma Physics	Vacant
High Latitude Ionospheric Physics	H. Chivers
Atmospheric Collision Processes	E. E. Ferguson
Ionosphere and Exosphere Scatter	K. L. Bowles
Airglow and Aurora	F. E. Roach
Ionospheric Radio Astronomy	R. S. Lawrence

*Located at Boulder, Colo.

Visual Landing Aids Field Laboratory	Arcata, Calif.
Master Railway Track Scale Depot	Clearing, Ill.
Materials Testing Laboratories:	Denver, Colo.
	Seattle, Wash.

Institute for Basic Standards Field Stations

Radio Standards Laboratory Field Stations:	
Standard Frequency Station WWV	Greenbelt, Md.
Standard Frequency Station WWVL–WWVB	Fort Collins, Colo.
Standard Frequency Station WWVH	Maui, Hawaii
Laboratory Astrophysics Division Field Station:	
Poor Man's Relief Mine, Four-Mile Canyon	Boulder, Colo.

Central Radio Propagation Laboratory Field Stations

ALASKA
Adak**
Anchorage
Barrow
College**
Cape Sarichef**

ANTARCTICA
Byrd Station**
Eights Station**
Pole Station**
USNS *ELTANIN* (Floating Research Vessel)**

ARIZONA
Kitt Peak Observatory

AUSTRALIA
Cook**
Sydney**

BOLIVIA
La Paz**

BRAZIL
Natal**
Sao Jose Dos Campos**

CALIFORNIA
Lompoc PMR

CANADA
Baie St. Paul
Cape Jones**
Frobisher Bay**
Great Whale River**

CANARY ISLANDS**

CANTON ISLANDS**

CHILE
Concepcion**
Santiago**

COLOMBIA
Bogota**

COLORADO
Akron
Beulah
Brighton
Cheyenne Mountain
Erie
Fritz Peak
Green Mountain Mesa
Gunbarrel Hill
Hanover
Haswell
Karval
Kendrick
Kolb
Lafayette
Lee Hill
North Boulder
Rocky Flats
Sunset
Table Mountain

ECUADOR
Quito**

GREENLAND
Godhavn**
Narssarssuaq**
Thule**

HAWAII
Kauai (Kekaha)
Maui (Kealia Pond)
Maui (Puunene Airport)

ICELAND
Keflavik**
Reykjavik**

ILLINOIS
Long Branch

INDIA
New Delhi**

JAPAN
Ohira**

KENYA
Nairobi**

MALAGASAY (MADAGASCAR)
Tananarive**

MALAYA
Singapore**

MINNESOTA
Cedar Creek**

MISSOURI
Warrensburg

MOROCCO
Rabat**

NEBRASKA
Shickley

NEW JERSEY
Fort Monmouth**

NEW MEXICO
White Sands**

NEW ZEALAND
Waimate**

NIGERIA
Kano**
Zaria**

OKINAWA
Okuma**
Onna**

**Contract or Mutual Cooperation

OKLAHOMA
Mangum

PANAMA CANAL ZONE
Balboa**

PERU
Lima**
Jicamarca Radio Observatory

PHILIPPINE ISLANDS
Manila**

SOUTH AFRICA
Pretoria**
Johannesburg**

SWEDEN
Enkoping**

VIRGINIA
Fort Belvoir
Front Royal
Wallops Island

WEST INDIES
Jamaica**

WYOMING
Bill

3.2. SUMMARY OF NBS STAFF

As of June 30, 1964

	Washington	Boulder	Total
Total permanent staff	2, 675	1, 230	3, 905
Other staff*	254	221	475
Total on rolls	2, 929	1, 451	4, 380
Research associates and guest workers	140	37	177
Total on rolls at NBS	3, 069	1, 488	4, 557
Professional staff:**			
Physicists	453	238	691
Chemists	295	9	304
Engineers	173	198	371
Mathematicians	52	52	114
Other	98	17	115
Total professional staff	1, 071	524	1, 595

*Intermittent, consultants, students, teachers, postdoctoral fellows, and temporary limited employees.
**Full-time permanent (excludes any under *).

3.3. FINANCIAL DATA ON NBS PROGRAM

The activities of the National Bureau of Standards are financed from three sources: from appropriations provided by the Congress; from payments by other agencies for specific research and development tasks; and from payments by industrial concerns, universities, research institutions, and government agencies for specific calibration or testing services. The following tabulation is a summary of the financial aspects of the Bureau programs for 1964:

**Contract or Mutual Cooperation.

Program and Source of Financing	Obligations Incurred (Rounded)		
Supported by NBS Appropriations:			
Operating Programs:			
Research & Technical Services....	$28,117,000		
Salaries and Expenses (Office of Technical Services)............	987,000		
Civilian Industrial Technology....	248,000		
Special Foreign Currency Program.	657,000		
Subtotal................	....	$30,009,000	
Construction and Facilities Program:			
Plant and Facilities.............	2,027,000		
Construction of Facilities.........	41,245,000		
Subtotal................	....	43,272,000	
Total NBS Appropriation..	....	....	$73,281,000
Supported by Other Funds:			
Research and Development Programs:			
Other Federal Agencies..........	17,693,000		
Nongovernmental Sources........	191,000		
Subtotal................	....	17,884,000	
Calibrations, Testing, Standard Samples and Other Technical Services...	....	5,832,000	
Federal Clearinghouse...............	....	1,509,000	
Reimbursable Administrative Services.	....	809,000	
Total Supported by Other Funds....................	....	....	26,034,000
Total Program...............	....	....	99,315,000

3.4. ADVISORY COMMITTEES

STATUTORY VISITING COMMITTEE

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

DR. E. R. PIORE, Vice President, Research & Engineering, International Business Machines Corporation (1967), Chairman
MR. CRAWFORD H. GREENWALT, President, E. I. du Pont de Nemours & Co. (1964)
PROFESSOR FREDERICK SEITZ, President, National Academy of Sciences (1966)
PROFESSOR CHARLES H. TOWNES, Provost, Massachusetts Institute of Technology (1965)
DR. ELMER W. ENGSTROM, President, Radio Corporation of America (1968)

TECHNICAL ADVISORY PANELS

Throughout the past year the Bureau's advisory input from the Nation's scientific and technical community functioned with increasing vigor and effectiveness. The National Academy of Sciences and National Research Council, in cooperation with the leading scientific and technical societies, increased the size and competence of the 18 NBS Advisory Panels to an average of slightly over 10 members per panel and reviewed the work of every technical division. Every panel held at least one meeting either at

NBS Washington or the Boulder Laboratories. Most Panels visited throughout the laboratories in connection with their meetings. Panel members were urged to critically evaluate the technical program in relation to overall national needs and to identify areas that should receive increased or decreased emphasis hypothesizing a constant total level of support. Written reports and recommendations have been received to date from 14 of the Panels and are being considered by the Institute Directors.

In addition to the foregoing, the NBS Advisory Committee on Calibration and Measurement Services met at both Boulder and Washington and made an unusually thorough critique of NBS calibration and measurement service activities. The NBS Weights and Measures Advisory Committee met immediately prior to the National Conference on Weights and Measures and served as an effective link between the Conference and the NBS.

Cooperating societies are: American Ceramic Society (ACerS); American Chemical Society (ACS); American Institute of Chemical Engineers (AIChE); Institute of Electrical and Electronic Engineers (IEEE); American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME); American Institute of Physics (AIP); American Society of Civil Engineers (ASCE); American Society of Mechanical Engineers (ASME); and Conference Board of the Mathematical Sciences (CBMS).

Dr. Paul D. Foote, National Research Council, Executive Secretary

Advisory Panel to Electricity Division

Prof. W. A. Lewis, Illinois Institute of Technology, Chairman (IEEE)
Dr. William G. Amey, Leeds & Northrup (IEEE)
Dr. Richard M. Bozorth, Short Hills, N.J. (AIP)
Dr. John Brainerd, University of Pennsylvania (IEEE)
Mr. Ivan G. Easton, General Radio Company (IEEE)
Prof. Henry B. Linford, Columbia University (ACS)
Mr. J. T. Lusignan, The Ohio Brass Company (IEEE)
Prof. M. B. Stout, University of Michigan (IEEE)
Prof. John G. Trump, Massachusetts Institute of Technology (AIP)

Advisory Panel to Metrology Division

Dr. Brian O'Brien, Pomfret, Conn., Chairman (AIP)
Dr. J. H. Webb, Eastman Kodak Company, Vice Chairman (AIP)
Prof. Isay A. Balinkin, University of Cincinnati (ACerS)
Dr. Alsoph H. Corwin, The Johns Hopkins University (ACS)
Mr. C. L. Crouch, Illuminating Engineering Society (AL)
Mr. A. M. Dexter, Bausch & Lomb Incorporated (AL)
Dr. Robert E. Hopkins, University of Rochester (AL)
Mr. Floyd W. Hough, American Geophysical Union (ASCE)
Dr. Elmer Hutchisson, American Institute of Physics (AIP).
Mr. J. J. Moran, Kimble Glass Company (ACerS)
Mr. Louis Polk, Dayton, Ohio (ASME)
Prof. John Strong, The Johns Hopkins University (AIP)

Advisory Panel to Heat Division

Prof. Joseph E. Mayer, University of California, Chairman (ACS)
Prof. Henry A. Fairbank, Duke University (AIP)
Prof. H. R. Griem, University of Maryland (AIP)
Dr. Burgess H. Jennings, Northwestern University (ASME)
Prof. Joseph Kestin, Brown University (ASME)
Dr. P. G. Klemens, Westinghouse Research Laboratories (AIP)
Prof. Robert S. Mulliken, University of Chicago (AIP)
Prof. John Ross, Brown University (ACS & AIP)
Dr. Charles Squire, Agriculture and Mechanical College of Texas (AIP)
Prof. Clayton A. Swenson, Iowa State University (AIP)
Prof. Edgar F. Westrum, Jr., University of Michigan (ACS)

Advisory Panel to Radiation Physics Division

Dr. A. O. Hanson, University of Illinois, Chairman (AIP)
Dr. John S. Blair, University of Washington (AIP)
Mr. Casimer J. Borkowski, Oak Ridge National Laboratory (AIP)
Dr. Robley D. Evans, Massachusetts Institute of Technology (AIP)
Dr. Harold A. Lamonds, Aerojet General Corporation (IEEE)
Dr. John S. Laughlin, Sloan-Kettering Institute for Cancer Research (AIP)
Dr. H. M. Parker, General Electric Company (AIP)
Prof. George T. Reynolds, Palmer Physical Laboratory (AIP)
Prof. Harald H. Rossi, Columbia University (AL)
Dr. Vance L. Sailor, Brookhaven National Laboratory (AIP)
Dr. Warren K. Sinclair, Argonne National Laboratory (AL)
Prof. Anthony Turkevich, University of Chicago (AL)

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Prof. Clark E. Bricker, University of Kansas (ACS)
Dr. Norman D. Coggeshall, Gulf Research & Development Company (AIP)
Prof. W. D. Cooke, Cornell University (ACS)
Prof. George Morrison, Cornell University (ACS)
Prof. Charles N. Reilley, University of North Carolina (ACS)
Prof. L. B. Rogers, Purdue University (ACS)
Dr. James White, Oak Ridge National Laboratory (ACS)
Prof. George T. Austin, State College of Washington (AICE)

Advisory Panel to Mechanics Division

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Prof. Lynn S. Beedle, Lehigh University (ASCE)
Prof. Arthur T. Ippen, Massachusetts Institute of Technology (ASCE)
Dean R. B. Lindsay, Brown University (AIP)
Dr. Harry F. Olson, Radio Corporation of America (AIP)
Prof. Jesse Ormondroyd, University of Michigan (ASME)
Dr. Milton Plesset, California Institute of Technology (AIP)
Dr. M. E. Shank, Pratt & Whitney Aircraft (ASME)

Advisory Panel to Polymers Division

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Dr. Raymond F. Boyer, Dow Chemical Company (ACS)
Dr. J. H. Dillon, Textile Research Institute (AIP)
Dr. Milton Harris, Harris Research Laboratories, Inc. (ACS)
Dr. Frank C. McGrew, E. I. du Pont de Nemours & Co. (ACS)
Dr. Charles C. Price, University of Pennsylvania (ACS)
Dr. J. F. Downie Smith, Carrier Research & Development Company (ASME)
Dr. Charles Scott Venable, Wallingford, Pennsylvania (ACS)
Dr. C. M. Blair, Union Carbide Corporation (AICE)

Advisory Panel to Metallurgy Division

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Dr. W. A. Dean, Aluminum Company of America (AIME)
Dr. D. J. Dienes, Brookhaven National Laboratory (AIP)
Dr. Morris E. Fine, Northwestern University (AIME)
Mr. A. R. Lytle, National Academy of Sciences-National Research Council (AIME)
Dr. Oscar Marzke, United States Steel Corporation (AIME)
Prof. E. F. Osborn, Pennsylvania State University (ACerS)
Dr. Joseph A. Pask, University of California (ACerS)
Dr. Albert J. Phillips, American Smelting & Refining Company (AIME)
Mr. J. H. Scaff, Bell Telephone Laboratories (AIME)
Prof. Robb M. Thomson, University of Illinois (AIP)

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Dr. Orson L. Anderson, Summit, New Jersey (ACerS)
Dr. C. L. Babcock, Owens-Illinois Technical Center (ACerS)
Dr. Morris Berg, General Motors Corporation (ACerS)
Prof. C. Ernest Birchenall, University of Delaware (AL)
Dr. Joseph E. Burke, General Electric Research Laboratory (ACerS)
Dr. James R. Johnson, Minnesota Mining & Manufacturing Company (ACerS)
Dr. Ralston Russell, Jr., the Ohio State University (ACerS)
Prof. Henry Taube, Stanford University (ACS)

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Prof. Jesse H. Day, Ohio University (ACS)
Dr. Albert G. H. Dietz, Massachusetts Institute of Technology (ASCE)
Dr. J. V. Fitzgerald, Tile Council of America, Inc. (ACerS)
Dr. Robert A. Hechtman, Planning Analysis & Design Corp. (ASCE)
Prof. James T. Lendrum, University of Florida (AIA)
Dean Warren L. McCabe, Polytechnic Institute of Brooklyn (AICE)
Dr. John S. Parkinson, Johns-Manville Products Corporation (AIP)
Prof. E. R. Queer, The Pennsylvania State University (AL)
Mr. Raymond C. Reese, Toledo, Ohio (ASCE)

Advisory Panel to Applied Mathematics Division

Prof. George E. Forsythe, Stanford University, Chairman (CBMS)
Prof. T. W. Anderson, Columbia University (CBMS)
Prof. Francis J. Anscombe, Yale University (AL)
Prof. Charles R. DePrima, California Institute of Technology (CBMS)
Prof. Joaquin B. Diaz, University of Maryland (CBMS)
Prof. William Feller, Princeton University (CBMS)
Dr. Ralph E. Gomory, International Business Machines Corporation (CBMS)
Dr. Alan J. Hoffman, International Business Machines Corporation (CBMS)
Dr. Alston S. Householder, Oak Ridge National Laboratory (CBMS)
Dr. Bernard O. Koopman, Institute for Defense Analyses (CBMS)
Dr. J. P. LaSalle, Research Institute for Advanced Studies (CBMS)
Prof. Peter D. Lax, Institute of Mathematical Sciences (CBMS)
Dr. Elliott W. Montroll, Institute for Defense Analyses (CBMS)
Prof. R. D. Richtmyer, New York University (CBMS)
Dr. J. Barkley Rosser, University of Wisconsin (CBMS)
Prof. M. M. Schiffer, Stanford University (CBMS)
Prof. John Todd, California Institute of Technology (CBMS)

Advisory Panel to Data Processing Systems Division

Dr. Alston S. Householder, Oak Ridge National Laboratory, Chairman (CBMS)
Prof. George E. Forsythe, Stanford University (CBMS)
Dr. Alan J. Hoffman, International Business Machines Corp. (CBMS)
Mr. John C. McPherson, International Business Machines Corporation (IEEE)
Prof. Charles L. Miller, Massachusetts Institute of Technology (ASCE)
Mr. William Papian, Massachusetts Institute of Technology (IEEE)
Prof. Morris Rubinoff, University of Pennsylvania (IEEE)
Dr. Abraham Sinkov, Arizona State University (CBMS)

Advisory Panel to Atomic Physics Division and Joint Institute for Laboratory Astrophysics

Prof. Peter Franken, University of Michigan, Chairman (AIP)
Dr. R. Grant Athay, University of Utah (AL)
Prof. W. R. Bennett, Jr., Yale University (AIP)
Dr. Bruce H. Billings, Pacific Palisades, California (AIP)
Prof. R. H. Dicke, Princeton University (AIP)
Dr. Wade L. Fite, University of Pittsburgh (AIP)
Dr. Leo Goldberg, Harvard College Observatory (AIP)
Prof. Jesse L. Greenstein, California Institute of Technology (AL)
Prof. Vernon W. Hughes, Yale University (AIP)
Dr. R. L. Sproull, Advanced Research Projects Agency (AIP)
Prof. Gabriel Weinreich, University of Michigan (AIP)
Dr. M. Kent Wilson, Tufts University (ACS)

Advisory Panel to Instrumentation Division

Mr. R. W. Larson, General Electric Research Laboratories, Chairman (IEEE)
Dr. A. O. Beckman, Beckman Instruments, Inc. (AL)
Mr. Ivan G. Easton, General Radio Company (IEEE)
Mr. William R. Hewlett, Hewlett-Packard Company (IEEE)
Dr. R. J. Jeffries, Data-Control Systems, Inc. (AL)
Colonel J. Z. Millar, Western Union Telegraph Company (IEEE)
Mr. Leon Podolsky, Sprague Electric Company (IEEE)
Dr. Richard C. Webb, Colorado Instruments, Inc. (IEEE)

Advisory Panel to Physical Chemistry Division

Prof. Henry Eyring, University of Utah, Chairman (ACS)
Dr. Paul Cross, Mellon Institute (ACS)
Dr. Benjamin P. Dailey, Columbia University (ACS)
Prof. Hans H. Jaffe, University of Cincinnati (ACS)
Dr. Joseph O. Hirschfelder, University of Wisconsin (ACS)
Dr. Max S. Matheson, Argonne National Laboratory (ACS)
Dr. Daniel R. Stull, The Dow Chemical Company (ACS)

Advisory Panel to Cryogenic Engineering Division

Dr. Clyde McKinley, Air Products Incorporated, Chairman (AICE)
Dr. E. F. Hammel, University of California (AIP)
Prof. A. L. Hesselschwerdt, Massachusetts Institute of Technology (ASME)
Prof. Edward Lady, University of Michigan (ASME)
Dr. Hugh M. Long, Union Carbide Corporation (AIP)
Dr. Loyd B. Nesbitt, General Electric Laboratory (AIP)
Dr. David White, Ohio State University (ACS)

Advisory Panel to Central Radio Propagation Laboratory

Prof. Arthur H. Waynick, The Pennsylvania State University, Chairman (IEEE)
Mr. Stuart L. Bailey, Alexandria, Virginia (IEEE)
Dr. C. M. Crain, The Rand Corporation (IEEE)
Mr. Milton Greenberg, Geophysics Corporation of America (AL)
Dr. S. W. Herwald, Westinghouse Electric Corporation (IEEE)
Dr. F. S. Johnson, Graduate Research Center (AIP)
Dr. John M. Kelso, ACF Industries, Inc. (IEEE)
Prof. W. J. Ross, The Pennsylvania State University (IEEE)
Prof. John B. Smyth, The Pennsylvania State University (AIP)
Dean George Town, Iowa State University (IEEE)
Dr. O. G. Villard, Stanford University (IEEE)

Advisory Panel to Radio Standards Laboratory

Prof. Arthur A. Oliner, Polytechnic Institute of Brooklyn, Chairman (IEEE)
Dr. Sidney A. Bowhill, University of Illinois (IEEE)
Prof. Walter Gordy, Duke University (AIP)
Prof. E. L. Hahn, University of California (AIP)
Dr. E. W. Houghton, Bell Telephone Laboratories (IEEE)
Prof. E. C. Jordan, University of Illinois (IEEE)
Dr. R. Kompfner, Bell Telephone Laboratories (IEEE)
Prof. W. A. Lewis, Illinois Institute of Technology (IEEE)
Dr. Bernard M. Oliver, Hewlett-Packard Company (IEEE)
Prof. N. F. Ramsey, Harvard University (AIP)
Dr. John C. Simons, Jr., Weston, Massachusetts (IEEE)
Prof. M. W. P. Strandberg, Massachusetts Institute of Technology (AIP)

ADVISORY COMMITTEE ON ENGINEERING AND RELATED STANDARDS

(Members are nominated by the American Standards Association (ASA) and the American Society for Testing and Materials (ASTM))

Dr. I. C. Schoonover, National Bureau of Standards, Chairman
Mr. Roger E. Gay, American Standards Association (ASA)
Mr. Richard T. Kropf, Belding Heminway Company (ASTM)
Mr. John W. McNair, American Standards Association (ASA)
Mr. N. L. Mochel, Westinghouse Electric Corporation (ASTM)
Mr. Frank H. Roby, American Standards Association (ASA)
Mr. Alfred C. Webber, E. I. du Pont de Nemours, Inc. (ASTM)

ADVISORY COMMITTEE ON CALIBRATION AND MEASUREMENT SERVICES

(Members are appointed on the basis of their broad personal knowledge of industrial measurement problems)

Mr. W. A. Wildhack, National Bureau of Standards, Chairman
Mr. Joseph M. Aldrich, San Gabriel, California
Dr. William G. Amey, Leeds & Northrup Company
Mr. Ivan G. Easton, General Radio Company
Mr. Charles E. Johnson, The Boeing Company
Mr. E. C. Lloyd, National Bureau of Standards
Mr. Sheldon C. Richardson, General Electric Company
Dr. George Sonneman, United Aircraft Corporate Systems Center
Mr. Bruno Weinschel, Weinschel Engineering
Mr. Charles E. White, Avco Research & Advanced Development Division
Mr. L. B. Wilson, Sperry Gyroscope Company

WEIGHTS AND MEASURES ADVISORY COMMITTEE

(Members are nominated by the National Conference on Weights and Measures)

Mr. M. W. Jensen, National Bureau of Standards, Chairman
Miss Genevieve Blatt, Secretary of Internal Affairs, Commonwealth of Pennsylvania
Mr. John Hoyt Chaloud, Ivorydale Technical Center
Mr. C. G. Gehringer, The Hobart Manufacturing Company
Mr. Rollin E. Meek, State Board of Health, Indiana
Mr. Arch W. Troelstrup, Stephens College
Mr. Donald Malcolm Turnbull, City of Seattle, Comptrollers Department

3.5. AWARDS AND HONORS

Recognition of the Bureau's contributions to science and technology often takes the form of awards and honors from Government, academic, professional, and industrial groups. The following list reflects such recognition bestowed on Bureau staff members during fiscal year 1963.

Recipient	*Award*
Astin, Allen V.	Rockefeller Public Service Award
Bates, A. Allan	Stanton Walker Lecture Award from University of Maryland
Costrell, Louis	Elected Fellow of Washington Academy of Sciences
Diamond, Jacob J.	Elected Fellow of Washington Academy of Sciences
Landgrebe, Albert R.	Superior Service Unit Award from Department of Agriculture
Logan, Hugh L.	Burgess Memorial Award by American Society of Metals
Madden, Robert P.	Elected Fellow of Optical Society of America
Malitson, Irving	Elected Fellow of Optical Society of America
Marton, Ladislaus	Special Medal of University of Brussels Elected Honorary Member of Electron Microscopy Society of France
McCamy, Calvin S.	Elected Fellow of Optical Society of America
Meijer, Paul	Fellowship from John Simon Guggenheim Memorial Foundation
Ordway, Fred	Elected Fellow of American Ceramic Society
Paffenbarger, George C.	Elected to Honorary Membership in National Dental Association

Passaglia, Elio	Elected Fellow of American Physical Society Elected to Executive Committee, American Physical Society Division of High Polymer Physics
Scribner, Bourdon F.	Elected to Membership in Society of Sigma Xi
Sitterly, Charlotte M.	Annie Jump Cannon Centennial Medal from Wesley College
Smith, Jack C.	Elected Fellow of American Physical Society Elected Member of Textile Institute
Wachtman, John B., Jr.	Elected Fellow of American Ceramic Society Certificate of Service by Gordon Research Conference
Wait, James R.	Arthur S. Flemming Award Harry Diamond Memorial Prize
Walker, Raymond F.	Elected Fellow of American Ceramic Society
Wyckoff, H. O.	Medal from Radiological Society of North America

DEPARTMENT OF COMMERCE EXCEPTIONAL SERVICE AWARDS (Gold Medal)

Recipient	*Technical Area*
Alexander, Samuel N.	Data Processing
Allen, Harry C., Jr.	Molecular Spectroscopy
Cook, Richard K.	Acoustics
George, William D. (Deceased Feb. 12, 1963)	Radio Standards
Little, C. Gordon	Radio Propagation
Richardson, John M.	Radio Standards
Rosenberg, Samuel J.	Metallurgy

DEPARTMENT OF COMMERCE MERITORIOUS SERVICE AWARDS (Silver Medal)

Recipient	*Technical Area*
Allred, Charles M.	High Frequency Measurements
Beehler, Roger E.	Atomic Frequency and Time Interval Standards
Brauer, Gerhard M.	Dental Research
Cooper, John W.	Absorption Spectra of Rare Gases
Cox, Orson H.	Concreting Materials
Eisenstein, Julian C.	Solid State Physics
French, Judson C.	Semiconductor Technology
Graef, Alois N.	Scientific Instruments Craftmanship
Hardy, Robert C.	Viscosity Standards
Janes, Harris B.	Radio Distance Measuring Techniques
Megill, Lawrence R.	Upper Atmosphere and Space Physics
Miller, Howard S.	Scientific Instruments Craftmanship
Ogburn, Fielding	Electroplating Technology
Outman, Alice G.	Administrative Duties in Director's Office
Powell, Robert C.	Radio and Electronic Measurements
Schafer, George E.	Radio Standards
Schweitzer, Walter G.	Wavelength Standards
Joint Award: Codling, Keith Madden, Robert P.	Far Ultraviolet Physics
Group Award: Simpson, John A. Kuyatt, Chris E. Mielczarek, Stanley R.	Far Ultraviolet Physics

3.6. EDUCATION, TRAINING, AND UNIVERSITY LIAISON

A broad employee development program which is implemented primarily through both the NBS Graduate School and nongovernment educational and training facilities is available to all staff members. The program covers educational levels through postdoctoral research. The program is offered at both the Boulder and Washington Laboratories; its primary objectives are the increase of efficiency in the conduct of official assigned duties and the systematic preparation for increased responsibilities.

The Graduate School curriculum includes graduate and undergraduate courses in the physical sciences, mathematics, and certain branches of engineering. Also, a series of scientific colloquia and seminars are led by research leaders from the Bureau staff and from other research centers. In addition, general staff development courses, such as scientific German, practical metallurgy, and mathematical symbolism and terminology, are also offered. Educational counseling is available, and employees may receive thesis accreditation for research done at the Bureau.

Since the educational requirements of staff members are varied and changing, the NBS Educational Committee determines course offerings on the basis of periodic need surveys. The program is flexible, including both NBS in-hours courses and NBS-university-sponsored out-of-hours courses. The Technician Career Program, established in 1960, offers a series of in-hours courses on the fundamentals of science and mathematics. The Program helps increase job efficiency and offers educational opportunities to subprofessional laboratory personnel. Since the establishment of the Washington educational program in 1908, 42 universities have awarded 308 graduate degrees based partly on credits obtained or thesis work carried on under the NBS Graduate School Program.

The Bureau has expanded the Graduate Program at Boulder through the establishment of a Joint-Course program and an Adjoint Professor plan with the University of Colorado. Various graduate departments at both the NBS Graduate School and the University offer courses simultaneously, with benefits to both the Government and the University. Bureau staff members who teach the courses have the title of Adjoint Professor at the University.

Nongovernment training, authorized by the Government Employees Training Act of 1958, falls into three major categories. These are:

1. Full-time (3 to 12 months) postdoctoral study and research assignments at universities and research centers, both in this country and abroad.

2. Full-time (less than 3 months) attendance at institutes, seminars, short concentrated courses, workshops, etc. Generally, these are offered through the educational facilities of major universities and industrial laboratories throughout the country.

3. Part-time, job-related academic courses at local educational institutions, generally in early evening classes.

Four hundred and seventy-two staff members at Washington and Boulder were trained through non-Government facilities in 1964; 16 career scientists were selected for full-time research assignments at universities and research centers. Participants in approved full-time non-Government training programs receive full salary and expenses, including tuition, related fees, travel, and per diem, as well as transportation of family and household effects.

Short concentrated courses and training programs at universities and in industry were attended by 156 Washington and Boulder staff members. Three hundred employees, mostly from technical divisions, attended job-related courses at local educational facilities.

Another important area of Government-sponsored programs since the Training Act is the Inter-agency series of courses sponsored primarily by the Civil Service Commission. One hundred and eighty-nine Bureau employees participated in a wide range of special courses with a sizable number in the supervisory-management fields.

The Bureau sponsors a student trainee summer program for college students majoring in the physical sciences, mathematics, and certain branches of engineering. Each summer an integrated work-study program including lectures, tours, demonstrations, supervised laboratory assignments, and professional counseling, is conducted. The program acquaints young people interested in career scientific research opportunities with the work being done at NBS. One of the purposes of the program is to help in preparing talented students for scientific careers. The students participating in the program come from schools throughout the country; many of the participants in the program are graduate students.

In collaboration with the National Research Council, the Graduate School offers postdoctoral resident research associateships to young scientific investigators of unusual ability and promise of becoming creative leaders in basic research in the various branches of the physical and mathematical sciences. While acquiring basic knowledge, they have opportunities to develop new scientific approaches and laboratory skills, and thus advance scientific knowledge. Twenty new Research Associateships (tenable at both the Washington and Boulder Laboratories) are open each year. During 1964 the following young men were selected and served: Walter Braun, John M. Crissman, Richard A. Durst, Clyde K. Edmiston, Lewis J. Fetters, Fred Gross, David L. Hogenboom, Marcel Holberstadt, Arthur Hyman, William H. Kirchhoff, John E. Lagnese, Theodore E. Madey, Roland J. Miech, Raymond D. Mountain, Ralph D. Nelson, Jr., Paul Peyser, Mark Sharnoff, and John T. Yates, Jr.

Scientific staff meetings, held weekly from September through May, are also included in the Bureau's educational program. The staff meetings are of a less specialized nature than colloquia and seminars offered in the Graduate School program. They are open to all professional staff members of the Bureau and to scientific personnel from neighboring laboratories.

Visiting Scientists. The Bureau encourages distinguished scientists to spend their sabbatical years, summer vacations, or other extended periods at the Bureau. Such a program increases the Bureau's ties with the Nation's universities and provides a continuing influx of new ideas into the Bureau's programs. To increase the flexibility and usefulness of the visiting scientist program, the Bureau is seeking legislation that will provide selective procedures making it possible to reimburse visiting scientists for the necessary travel and transportation of household effects.

The largest visiting scientist program at the Bureau is at the Joint Institute for Laboratory Astrophysics; during the past year 18 scientists were involved in the JILA program. In other parts of the Bureau there were 30 visiting scientists—9 in Washington and 21 in the Boulder Laboratories.

3.7. PUBLICATIONS* AND PATENTS

Publications in the Bureau's Series

Journal of Research. Contains full research papers, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Advances in measurement standards and techniques . . . physical constants . . . properties of materials . . . instrumentation . . . radio propagation.

The Journal is published in four separate sections . . .

A. Physics and Chemistry, issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75; single copy, 70 cents.

B. Mathematics and Mathematical Physics, issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75; single copy, 75 cents.

C. Engineering and Instrumentation, issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75; single copy, 75 cents.

D. Radio Science (formerly Radio Propagation), issued monthly. Annual subscription: Domestic, $9; foreign, $11.50; single copy, $1.00.

Volume 67A (Phys. and Chem.), No. 4 (July–Aug. 1963)

Symmetry splitting of equivalent sites in oxide crystals and related mechanical effects. J. B. Wachtman, Jr., H. S. Peiser, and E. P. Levine.

Relaxation modes for trapped crystal point defects. A. D. Franklin.

A note on the galvanomagnetic and thermoelectric coefficients of tetragonal crystalline materials. W. C. Hernandez, Jr., and A. H. Kahn.

Photolytic behavior of silver iodide. G. Burley.

Correlation of muscovite sheet mica on the basis of color, apparent optic angle, and absorption spectrum. S. Ruthberg, M. W. Barnes, and R. H. Noyce.

Thermodynamic properties of magnesium oxide and beryllium oxide from 298 to 1,200 °K. A. C. Victor and T. B. Douglas.

Heat exchange in adiabatic calorimeters. E. D. West.

Preparation of anhydrous single crystals of rare-earth halides. N. H. Kiess.

A phase study of the system: oxalic acid/acetic acid/water; its significance in oxalic acid crystal growth. J. Strassburger and J. L. Torgesen.

Wavelength calibrations in the far infrared (30 to 1000 microns). K. N. Rao, R. V. de Vore, and E. K. Plyler.

On the fourth order Hamiltonian of an asymmetric rotor molecule of orthorhombic symmetry. W. B. Olson and H. C. Allen, Jr.

Measurement of the thickness and refractive index of very thin films and the optical properties of surfaces by ellipsometry. F. L. McCrackin, E. Passaglia, R. R. Stromberg, and H. L. Steinberg.

Color phenomena associated with energy transfer in afterglows and atomic flames. A. M. Bass and H. P. Broida.

Volume 67A (Phys. and Chem.), No. 5 (Sept.–Oct. 1963)

Reduction of space groups to subgroups by homogeneous strain. H. S. Peiser, J. B. Wachtman, Jr., and R. W. Dickson.

High-temperature thermodynamic functions for zirconium and unsaturated zirconium hydrides. T. B. Douglas.

Heat of oxidation of aqueous sulfur dioxide with gaseous chlorine. W. H. Johnson and J. R. Ambrose.

Thickness of adsorbed polystyrene layers by ellipsometry. R. R. Stromberg, E. Passaglia, and D. J. Tutas.

Melting temperature and change of lamellar thickness with time for bulk polyethylene. J. J. Weeks.

Precise coulometric titrations of potassium dichromate. G. Marinenko and J. K. Taylor.

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*Publications for which a price is indicated are available by purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 (foreign postage, one-fourth additional). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

Resolution limits of analyzers and oscillatory systems. E. L. R. Corliss.
Synthesis, purification, and physical properties of seven twelve-carbon hydrocarbons. T. W. Mears, C. L. Stanley, E. L. Compere, Jr., and F. L. Howard.
Reactions of polyflurobenzenes with nucleophilic reagents. L. A. Wall, W. J. Pummer, J. E. Fearn, and J. M. Antonucci.

Volume 67A (Phys. and Chem.), No. 6 (Nov.–Dec. 1963)

Analysis of the spectrum of neutral atomic bromine (Br I). J. L. Tech.
Matrices of spin-orbit interaction in the electron configuration $np^2\ n'\ p$ and $np^4\ n'\ p$. J. L. Tech.
A study of the gas-stabilized arc as an emission source for the measurement of oscillator strengths. Determination of some relative *gf*-values for Fe I. M. Margoshes and B. F. Scribner.
Tritium-labeled compounds. IX. Determination of isotope effects in reactions yielding water-*t* from nonvolatile reactants. Oxidation of aldoses-*l-t* with iodine. H. S. Isbell and L. T. Sniegoski.
Buffer solutions of potassium dihydrogen phosphate and sodium succinate at 25° C. M. Paabo, R. G. Bates, and R. A. Robinson.
Recalibration of the NBS glass standards of spectral transmittance. H. J. Keegan, J. C. Schleter, and M. A. Belknap.
Thermal behavior of muscovite sheet mica. S. Ruthberg.
Absolute configuration and chemical topology. S. J. Tauber.
Reversibility of polyester adsorption on glass. R. R. Stromberg and W. H. Grant.
Chemical purity by dielectric cryometry. G. S. Ross and L. J. Frolen.
Adsorption, desorption, resorption. W. V. Loebenstein.
Color phenomena in polymer fracture. S. B. Newman and I. Wolock.

Volume 68A (Phys. and Chem.), No. 1 (Jan.–Feb. 1964)

Fast neutron dose measurements for a D–D source in water. W. B. Beverly and V. Spiegel, Jr.
X-ray spectrometric analysis of noble metal dental alloys. B. W. Mulligan, H. J. Caul, S. D. Rasberry, and B. F. Scribner.
The first spectrum of manganese, Mn I. M. A. Catalán, W. F. Meggers, and O. Garcia-Riquelme.
Transition probabilities of forbidden lines. R. H. Garstang.
Franck-Condon factors to high vibrational quantum numbers III: CN. R. W. Nicholls.
Infrared absorption spectrum of nitrous oxide (N_2O) from 1830 cm^{-1} to 2270 cm^{-1}. E. K. Plyler, E. D. Tidwell, and A. G. Maki.
An absolute light scattering photometer: II. Direct determination of scattered light from solutions. D. McIntyre.
High pressure microscopy of the silver and cuprous halides. A. Van Valkenburg.
Lattice parameters and lattice energies of high-pressure polymorphs of some alkali halides. C. E. Weir and G. J. Piermarini.
Calculation of the higher order dipole-dipole effect in paramagnetic crystals. P. H. E. Meijer.
Second and third virial coefficients for hydrogen. R. D. Goodwin, D. E. Diller, H. M. Roder, and L. A. Weber.
Heats of solution, transition, and formation of three crystalline forms of metaboric acid. M. V. Kilday and E. J. Prosen.

Volume 68A (Phys. and Chem.), No. 2 (Mar.–Apr. 1964)

Tritium-labeled compounds X. Isotope effects in the oxidation of aldoses-*l-t* with bromine. H. S. Isbell and L. T. Sniegoski.
Thermal degradation of fractionated high and low molecular weight polyisobutylene. D. McIntyre, J. H. O'Mara, and S. Straus.
Ionization constants of the six dichloroanilines and the six dichlorophenols in aqueous solution at 25° C. R. A. Robinson.
Stereoregularity in ionic polymerization of acenaphthylene. V. M. Story and G. Canty.
Dielectric behavior of the film formed on mica cleaved in moist air. S. Ruthberg and L. Frenkel.
On the measurement of dielectric losses and surface conductivity of dielectrics in parallel plane test capacitors. L. Frenkel.
Polymorphism of bismuth sesquioxide. I. Pure Bi_2O_3. E. M. Levin and R. S. Roth.
Polymorphism of bismuth sesquioxide. II. Effect of oxide additions on the polymorphism of Bi_2O_3. E. M. Levin and R. S. Roth.
Second spectrum of tungsten (W II). D. D. Laun.

Volume 68A (Phys. and Chem.), No. 3 (May–June 1964)

Compressibility of natural rubber at pressures below 500 kg/cm^2. L. A. Wood and G. M. Martin.
A copolymer with lamellar morphology. R. K. Eby.
Variation of glass temperature with pressure in polypropylene. E. Passaglia and G. M. Martin.
Perfluorophenyl ether and related polymers. W. J. Pummer and L. A. Wall.
Cyclic polyhydroxy ketones II. *xylo*-Trihydroxycyclohexenediolic acid and keto-inositols. A. J. Fatiadi and H. S. Isbell.
Tritium-labeled compounds. XI. Mechanism for the oxidation of aldehydes and aldoses-*l–t* with sodium chlorite. H.S. Isbell and L. T. Sniegoski.
Medium effects on the dissociation of weak acids in methanol-water solvents. E. E. Sager, R. A. Robinson, and R. G. Bates.
Crystallization of anhydrous copper sulfate from sulfuric acid—ammonium sulfate mixtures. P. M. Gruzensky.
Detection of lattice deformation and recovery in epsilon phase silver-tin alloys. R. M. Waterstrat and G. E. Hicho.
Vapor pressures of ruthenium and osmium. N. J. Carrera, R. F. Walker, and E. R. Plante.
The O–2 transition of CO in condensed oxygen, nitrogen, and argon. S. Abramowitz and H. P. Broida.

Volume 67B (Math. and Math. Phys.), No. 3 (July–Sept. 1963)

Remarks on hypo-elasticity. C. Truesdell.
Error bounds in the pointwise approximation of solutions of elastic plate problems. J. H. Bramble and L. E. Payne.
Effect of error in measurement of elastic constants on the solutions of problems in classical elasticity. J. H. Bramble and L. E. Payne.
Eigenfunctions of the f^3 configuration. J. C. Eisenstein.
Zeroes of first derivatives of Bessel functions of the first kind, $J_n'(x)$, $21 \leq n \leq 51$, $0 \leq x \leq 100$. G. W. Morgenthaler and H. Reismann.

Volume 67B (Math. and Math. Phys.), No. 4 (Oct.–Dec. 1963)

Zonal harmonic perturbations of an accurate reference orbit of an artificial satellite. J. P. Vinti.
Optimal periodic inspection programs for randomly failing equipment. G. H. Weiss.
An analysis of pedestrian queueing. G. H. Weiss.
Solutions of the equation $\Psi_{xx}+\frac{1}{x}\Psi_x+Kx^ne^{\Psi}=0$. E. A. Kearsley.
On the graphs of finite idempotent Boolean relation matrices. D. Rosenblatt.

Volume 68B (Math. and Math. Phys.), No. 1 (Jan.–Mar. 1964)

A note on a generalized elliptic integral. G. H. Weiss.
An asymptotic expansion for the multivariate normal distribution and Mills' ratio. H. Ruben.
Calculation of certain multiple generating functions. G. H. Weiss.
Some infinite sums involving zeros of $J_0(\chi)$. L. F. Epstein.
Optimal matchings and degree-constrained subgraphs. A. J. Goldman.
Effects of a distribution on gap acceptance functions on pedestrian queues. G. H. Weiss.
Gaussian wave functions for polyatomic molecules: integral formulas. M. Krauss.

Volume 68B (Math. and Math. Phys.), No. 2 (Apr.–June 1964)

Determinations based on duplication of readings. J. A. Speckman.
General application of Youden's rank sum test for outliers and tables of one-sided percentage points. T. A. Willke.
A generalization of Rennie's inequality. A. J. Goldman.
On the asymptotic joint normality of quantiles from a multivariate distribution. L. Weiss.
Fitting $y=\beta x$ when the variance depends on x. J. Van Dyke.
Existence of k-edge connected ordinary graphs with prescribed degrees. J. Edmonds.
Inequalities for solutions of mixed boundary value problems for elastic plates. J. H. Bramble and L. E. Payne.

Volume 67C (Eng. and Instr.), No. 3, (July–Sept. 1963)

Apparatus for the detection of piezoelectric coupling. L. Frenkel.
Large aperture interferometers with small beam dividers. J. B. Saunders.

A far-infrared vacuum grating spectrometer. L. R. Blaine.
Relation of emittance to other optical properties. J. C. Richmond.
Minimization of the arrestment error in one-pan, two-knife balance systems. H. A. Bowman and H. E. Almer.
Determination of residual thiosulfate in processed film. C. I. Pope.
Drag compensation and measurement with manned satellites: feasibility study. R. M. Langer and J. P. Vinti.
Surface flame propagation on cellulosic materials exposed to thermal radiation. D. Gross and J. J. Loftus.
Parallel reversible permeability measurement techniques from 50 kc/s to 3 Gc/s. C. A. Hoer and R. D. Harrington.

Volume 67C (Eng. and Instr.), No. 4 (Oct.–Dec. 1963)

Limitations on electron beam density of unipotential electron guns at low voltages. J. A. Simpson and C. E. Kuyatt.
New radiofrequency mass spectrometer having high duty cycle. R. M. Mills.
A power-series buildup factor formulation. Application to rectangular and off-axis disk source problems. J. H. Hubbell.
An alinement interferometer. J. B. Saunders.
Determination of optical path difference for a photographic objective. F. E. Washer and W. R. Darling.
Development of filters for a thermoelectric colorimeter. S. H. Emara and R. P. Teele.
Application of air bearings to an electrodynamic vibration standard. T. Dimoff and B. F. Payne.
Leak-resistant rotation seal for vacuum applications. F. L. Howard.
Studies on the tungsten-rhenium thermocouple to 2000 °C. D. B. Thomas.

Volume 68C (Eng. and Instr.), No. 1 (Jan.–Mar. 1964)

A Fabry-Perot spectrometer for high-resolution spectroscopy and laser work. K. D. Mielenz, R. B. Stephens, and K. F. Nefflen.
A variable impedance power meter, and adjustable reflection coefficient standard. G. F. Engen.
A laser with a multihole diaphragm. T. Morokuma.
Principles of cryometric impurity determination as applied to samples of small sizes. C. P. Saylor and G. S. Ross.
Reference tables for thermocouples of iridium-rhodium alloys versus iridium. G. F. Blackburn and F. R. Caldwell.

Volume 68C (Eng. and Instr.), No. 2 (Apr.–June 1964)

Fringe pattern of an oscillating Fabry-Perot interferometer. K. D. Mielenz.
Interferometer for testing extended surfaces such as surface plates and precision ways. J. B. Saunders and J. V. McDermott.
Ferrimagnetic resonance in polycrystalline ferrite and garnet disks at L-band frequencies. W. E. Case, R. D. Harrington, and L. B. Schmidt.
Changes in the influence of atmospheric humidity during fatigue of an aluminum alloy. J. A. Bennett.
The theory of a stable high-speed externally pressurized gas-lubricated bearing. H. Sixsmith and W. A. Wilson.
Infrared spectra of asphalts: some aspects of the changes caused by photooxidation. P. G. Campbell and J. R. Wright.

Volume 67D (Radio Prop.), No. 3 (May–June 1963)

Effects of radio wave propagation through midlatitude 6300 Å auroral arcs. J. R. Roach
Comparison of observed atmospheric radio refraction effects with values predicted through the use of surface weather observations. B. R. Bean and G. D. Thayer.
Ionospheric scattering effects in long-distance propagation. H. A. Whale.
Concerning solutions of the VLF mode problem for an anisotropic curved ionosphere. J. R. Wait.
On the statistical theory of electromagnetic waves in a fluctuating medium (I). K. Furutsu.
Reception of skywave signals near a coastline. J. B. Andersen.
Analysis and synthesis of nonuniform transmission lines or stratified layers. G. Latmiral, G. Franceschetti, and R. Vinciguerra.
Resonant characteristics of a corrugated sphere. J. R. Wait and C. M. Jackson.
Impedances of long antennas in air and in dissipative media. D. W. Gooch, C. W. Harrison, Jr., R. W. P. King, and T. T. Wu.

Reflection of VLF radio waves from an inhomogeneous ionosphere. Part I. Exponentially varying isotropic model. J. R. Wait and L. C. Walters.

Volume 67D (Radio Prop.), No. 4 (July–Aug. 1963)

Influence of the lower ionosphere on propagation of VLF waves to great distances. J. R. Wait.
Comments on a paper "Auroral Sporadic-*E* Ionization" by R. D. Hunsucker and L. Owren. J. M. Bullen and G. A. M. King.
Reply to J. M. Bullen and G. A. M. King's "Comments on a paper 'Auroral Sporadic-*E* Ionization' by Robert D. Hunsucker and Leif Owren." R. D. Hunsucker and L. Owren.
Optimum reception pattern of the Beverage wave antenna at very low frequencies. E. W. Seeley.
Effect of a dissipative medium of finite size on antenna measurement. K. Iizuka and R. W. P. King.
Some implications of aircraft interference patterns in troposcatter reception. J. A. Bradshaw.
Asymptotic behavior of the current on an infinite cylindrical antenna. K. S. Kunz.
A dipole approximation of the backscattering from a conductor in a semi-infinite dissipative medium. M. B. Kraichman.
Small electric and magnetic antennas with cores of a lossy dielectric. J. Galejs.

Volume 67D (Radio Prop.), No. 5 (Sept.–Oct. 1963)

Ionospheric VHF scattering near the magnetic equator during the International Geophysical Year. R. Cohen and K. L. Bowles.
Radio pulse propagation by a reflection process at the lower ionosphere. J. R. Johler.
Field of a horizontal magnetic dipole in the presence of a magnetoplasma halfspace. G. Tyras, A. Ishimaru, and H. M. Swarm.
Reflection of VLF radio waves from an inhomogeneous ionosphere. Part II. Perturbed exponential model. J. R. Wait and L. C. Walters.
Collisional detachment and the formation of an ionospheric *C* region. E. T. Pierce.
Magnetic torques and Coriolis effects on a magnetically suspended rotating sphere. J. C. Keith.
Radiation field characteristics of lightning discharges in the band 1 kc/s to 100 kc/s. W. L. Taylor.
Low-frequency radio propagation into a moderately rough sea. D. F. Winter.
VLF superdirective loop arrays. E. W. Seeley.
Curves of ground proximity loss for dipole antennas (a digest). L. E. Vogler and J. L. Noble.
Observations and results from the "hiss recorder," an instrument to continuously observe the VLF emissions. J. M. Watts, J. A. Koch, and R. M. Gallet.

Volume 67D (Radio Prop.), No. 6 (Nov.–Dec. 1963)

A radiometeorological study, part I. Existing radiometeorological parameters. J. A. Lane and B. R. Bean.
A radiometeorological study, part II. An analysis of VHF field strength variations and refractive index profiles. B. R. Bean, V. R. Frank, and J. A. Lane.
A radiometeorological study, part III. A new turbulence parameter. B. R. Bean, E. J. Dutton, J. A. Lane, and W. B. Sweezy.
Reflection of radio waves from undulating tropospheric layers. A. T. Waterman, Jr., and J. W. Strohbehn.
Oblique propagation of groundwaves across a coastline—Part I. J. R. Wait.
Oblique propagation of groundwaves across a coastline—Part II. J. R. Wait and C. M. Jackson.
On the index of refraction of air, the absorption and dispersion of centimeter waves by gases. G. Boudouris. Translated from French by G. W. Curtis.
A numerical approach to the solution of radio diffraction problems. J. K. Hargreaves and S. Hargreaves.
Inversion of radiowave absorption data to establish ionospheric properties. I. Nondeviative absorption. A. D. Wheelon.
Radiation in a lossless magneto-ionic medium at frequencies high relative to the electron gyrofrequency. J. W. Marini.
Radiation through cylindrical plasma sheaths. J. H. Harris.
Chart for determining the effects of ionospheric tilts using an idealized model. T. A. Croft and R. B. Fenwick.
Reflection of VLF radio waves from an inhomogeneous ionosphere. Part III. Exponential model with hyperbolic transition. J. R. Wait and L. C. Walters.
Families of distributions for hourly median power and instantaneous power of received radio signals. M. M. Siddiqui and G. H. Weiss.

Statistical methods in radar astronomy. Determination of surface roughness. H. S. Hayre.
Electrical conductivity of the Great Lakes. L. H. Doherty.

Radio Sci. J. Res. NBS/USNC–URSI, Vol. 68D, No. 1 (Jan. 1964)

Comparison of observed VLF attenuation rates and excitation factors with theory. A. D. Watt and R. D. Croghan.
Field intensity measurements at 10.2 kc/s over reciprocal paths. J. C. Hanselman, C. J. Casselman, M. L. Tibbals, and J. E. Bickel.
The propagation of VLF waves over distances between 1000 and 3000 km. B. Burgess.
Some experimental results concerning nonreciprocal east-west VLF wave propagation. B. Burgess.
An experimental study of the phase stability of VLF signals. D. E. Hampton.
Some particular observations on diurnal phase variations of VLF transmission received in Paris. B. Decaux and A. Gabry.
Periodic fading of VLF signals received over long paths during sunrise and sunset. D. D. Crombie.
Effects of wall perturbations in multimode waveguides. S. W. Maley and E. Bahar.
VLF utilization at NASA satellite tracking stations. C. H. Looney, Jr.
Long waves associated with disturbances produced in plasmas. H. Bremmer.
Some remarks on the Watson transformation and mode theory. L. A. Berry.
Concerning limitations and further corrections to geometric-optical theory for LF, VLF propagation between the ionosphere and the ground. J. R. Johler.
Some remarks on mode and ray theories of VLF radio propagation. J. R. Wait.
Two-dimensional treatment of mode theory of the propagation of VLF radio waves. J. R. Wait.
Reflection of electromagnetic waves from a lossy magnetoplasma. J. R. Wait and L. C. Walters.
Propagation of ELF waves below an inhomogeneous anisotropic ionosphere. J. Galejs and R. V. Row.
VLF propagation under the ionosphere in the lowest mode of horizontal polarization. H. A. Wheeler.
Propagation of VLF waves under disturbed conditions. B. Burgess.
VLF disturbances caused by trapped beta-rays from the decay of neutrons produced in high-altitude nuclear explosions. A. J. Zmuda, B. W. Shaw, and C. R. Haave.
VLF anomalies observed at State College, Pa., during the U.S. 1962 high-altitude nuclear tests. C. F. Sechrist.

Radio Sci. J. Res. NBS/USNC–URSI, Vol. 68D, No. 2 (Feb. 1964)

Generation of an electromagnetic pulse by an expanding plasma in a conducting half-space. A. P. Stogryn and R. N. Ghose.
Impedance of a monopole antenna with a radial-wave ground system on an imperfectly conducting half-space, part II. S. W. Maley and R. J. King.
Capacitor type biconical antennas. J. Galejs.
Simulated angular response patterns for transhorizon propagation. J. W. Strohbehn and A. T. Waterman, Jr.
Radio-star scintillations from ionospheric waves. J. W. Warwick.
Ionosonde studies of some chemical releases in the ionosphere. J. W. Wright.
Diurnal changes of transmission time in the Arctic propagation of VLF waves. W. T. Blackband.
Geometrical optics convergence coefficient for the whistler case. J. H. Crary.
Comments on a paper, "Collisional Detachment and the Formation of an Ionospheric," by E. T. Pierce. H. R. Arnold.
The quasi-longitudinal approximation in the generalized theory of radio wave absorption. R. F. Benson.
Diurnal phase variation of VLF waves at medium distances. H. Volland.
Application of diffractions by convex surfaces to irregular terrain situations. H. T Dougherty and L. J. Maloney.
Effect of lossy earth on antenna gain. R. J. Coe and W. L. Curtis.
Propagation of radio waves with frequency 99.9 Mhz as a function of the vertical structure of the atmosphere derived from daily radiosonde observations. G. P. A. Braam.

Radio Sci. J. Res. NBS/USNC–URSI, Vol. 68D, No. 3 (Mar. 1964)

An interpretation of rapid changes in the phase of horizontally polarized VLF waves recorded at night over a short path in the Southwestern United States. E. E. Gossard and M. R. Paulson.

Precise phase and amplitude measurements on VLF signals propagated through the Arctic zone. F. H. Reder, C. J. Åbom, and G. M. R. Winkler.

On the long term phase stability of the 19.8 kc/s signal transmitted from Hawaii, and received at Boulder, Colorado. A. H. Brady.

Oblique propagation of groundwaves across a coastline—Part III. J. R. Wait.

Impedance of a monopole antenna with a radial-wire ground system on an imperfectly conducting half space—Part III. S. W. Maley and R. J. King.

A simplified theory of diffraction at an interface separating two dielectrics. J. Kane and S. N. Karp.

Variational solution for the admittance of a long cylindrical antenna. R. A. Hurd.

Admittance of annular slot antennas radiating into a plasma layer. J. Galejs.

Propagation of plasma waves in a "spoke-wheel" magnetic field. R. L. Liboff.

An experimental investigation of signal strength in the area around a transmitter's antipode. R. M. Pipp and J. B. Webster.

Relationship between simultaneous geomagnetic and ionospheric oscillations. H. Rishbeth and O. K. Garriott.

Radio Sci. J. Res. NBS/USNC–URSI, Vol. 68D, No. 4 (Apr. 1964)

Some basic microwave phase shift equations. R. W. Beatty.

A light-modulated scattering technique for diffraction field measurements. A. M. Vural and D. K. Cheng.

Radiation from an aperture in a coated plane. C. M. Knop and G. I. Cohn.

Impedance of a cylindrical dipole having a sinusoidal current distribution in a homogeneous anisotropic ionosphere. W. S. Ament, J. C. Katzin, M. Katzin, and B. Y.-C. Koo.

Propagation of electromagnetic waves through a continuously varying stratified anisotropic medium. G. H. Price.

Lunar semi-diurnal tides in $h'F$ and their influence on transequatorial radio propagation. J. A. Thomas.

Some statistical parameters related to the Nakagami-Rice probability distribution. W. R. Burns.

The U.S. National Committee Report for Commission 6 of URSI. Subcommission 6.3, Electromagnetics.

Radio Sci. J. Res. NBS/USNC, Vol. 68D, No. 5 (May 1964)

URSI National Committee Report, XIV General Assembly, Tokyo, September 1963:

Commission 1. Radio measurement methods and standards.
Commission 2. Tropospheric radio propagation.
Commission 3. Ionospheric radio.
Commission 4. Magnetospheric radio.
Commission 5. Radio and radar astronomy.
Commission 7. Radio electronics.

Radio Sci. J. Res. NBS/USNC–URSI, Vol. 68D, No. 6 (June 1964)

Electrical properties of sea ice at 0.1 to 30 Mc/s. F. L. Wentworth and M. Cohn.

ELF and VLF waves below aninhomogeneous anisotropic ionosphere. J. Galejs.

The effects of a small local change in phase velocity on the propagation of a VLF radio signal. D. D. Crombie.

Auroral-zone absorption effects on an HF arctic propagation path. R. D. Hunsucker.

Amplitude-probability distribution of atmospheric radio noise. P. Beckmann.

An approximate method for computing diffraction patterns caused by ionospheric irregularities. R. Gagnon.

Wave propagation in stratified random media. Y. M. Chen.

Radar scattering from coated perfect conductors: application to the semi-infinite cone and use of exact eikonal. H. Überall.

Technical News Bulletin. This monthly publication summarizes the current research, development, and test activities of the Bureau. The articles are brief, with emphasis on the results of research and their significance, chosen for their importance to other scientists, engineers, and to industry. Résumés of longer research reports, important national and international conferences on fundamental science in which the Bureau has represented the Nation, and bibliography of all publications by members of the staff as published are included. The Bulletin is designed to give a succinct account of the current work of the Bureau. (Annual subscription: domestic, $1.50; foreign, $2.25.)

Central Radio Propagation Laboratory Ionospheric Predictions: This is a monthly publication for those concerned with radio communication in determining the best skywave frequencies over any path at any time of day for average conditions for the month of prediction, which are made 3 months in advance. Charts of extraordinary-wave critical frequency for the *F*2 layer and of maximum usable frequency for a transmission distance of 4,000 km, of highest frequency of sporadic *E* in excess of 15 Mc/s are included. In addition, there are various maps, charts, diagrams, and nomograms needed to make practical application of the world-contour charts, together with examples of their use. (Annual subscription: domestic, $1.50; foreign, $2.00.)

Monographs. These are usually contributions to the technical literature which are too lengthy for publication in the Journal of Research. They often provide extensive compilations of information on subjects related to the Bureau's technical program. Until July 1959 most of this type of material was published in the Circular series.

27. Suppl. 1. Bibliography of temperature measurement, July 1960 to December 1962, C. Halpern. Sept. 13, 1963. 20 cents.
34. Vol. 2. Tables of chemical kinetics. Homogeneous reactions (supplementary tables), July 1, 1964. $2.00.
66. Electron optical studies of low-pressure gases, L. Marton, D. C. Schubert, and S. R. Mielczarek. Aug. 16, 1963. 35 cents.
67. Methods for the dynamic calibration of pressure transducers, J. L. Schweppe, L. C. Eichberger, D. F. Muster, E. L. Michaels, and G. F. Paskusz. Dec. 12, 1963. 60 cents.
68. Compilation of the melting points of the metal oxides, S. J. Schneider, Oct. 10, 1963. 25 cents.
69. Shielding against gamma rays, neutrons, and electrons from nuclear weapons, a review and bibliography, J. H. Hubbell and L. V. Spencer. Feb. 24, 1964. 30 cents.
72. Curves of input impedance change due to ground for dipole antennas, L. E. Vogler and J. L. Noble. Jan. 31, 1964. 35 cents.
73. The NBS standard hygrometer, A. Wexler and R. W. Hyland. May 1, 1964. 30 cents.
74. Creep and drying shrinkage of lightweight and normal-weight concretes, T. W. Reichard. March 4, 1964. 30 cents.

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

28. 1963 Supplement (1957), Parts I, II, III, Screw-thread standards for federal services. Oct. 15, 1963. 70 cents.
85. Physical aspects of irradiation. International Commission on Radiological Units and Measurements (ICRU) Report 10b, 1962. In press. Supersedes in part H78. Handbooks 84 through 89 will completely replace H78. 70 cents.
86. Radioactivity. International Commission on Radiological Units and Measurements (ICRU) Report 10c, 1962. Nov. 29, 1963. Supersedes in part H78 Handbooks 84 through 89 will completely replace H78. 40 cents.
87. Clinical dosimetry. International Commission on Radiological Units and Measurements (ICRU) Report 10d, 1962. Aug. 9, 1963. Supersedes in part H78. Handbooks 84 through 89 will completely replace H78. 40 cents.
89. Methods of evaluating radiological equipment and materials. International Commission on Radiological Units and Measurements (ICRU) Report 10f, 1962. Aug. 23, 1963. Supersedes in part H78. Handbooks 84 through 89 will completely replace H78. 35 cents.
91. Experimental statistics, M. G. Natrella. Aug. 1, 1963. $4.25.
92. Safe handling of radioactive material, W. R. Ney and L. S. Taylor. March 9, 1964. Supersedes Handbook 42. 40 cents.
93. Safety standard for nonmedical x-ray and sealed gamma-ray sources. Part I. General. Jan. 3, 1964. 30 cents.
96. Inspection of processed photographic record films for aging blemishes, C. S. McCamy. Jan. 24, 1964. 25 cents.
98. Examination of farm milk tanks, a manual for weights and measures officials, M. W. Jensen. May 22, 1964. 35 cents.

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

247. Weights and measures standards of the United States, a brief history, L. V. Judson, Oct. 1963 (Supersedes Sci. Paper No. 17 and Misc. Publ. 64). 35 cents.
248. Proceedings of the 1962 Standards Laboratory Conference. Aug. 16, 1963. $1.75.
249. Hydraulic research in the United States, 1963, H. K. Middleton. Aug. 9, 1963. $1.00.
250. Calibration and test services of the National Bureau of Standards. Nov. 22, 1963. 70 cents.
251. Bibliography on ignition and spark-ignition systems, G. F. Blackburn. Nov. 22, 1953. (Supersedes Circular 580). 15 cents.
252. Survey of the literature on safety of residential chimneys and fireplaces, H. Shoub. Dec. 17, 1963. 15 cents.
253. Recommended unit prefixes; defined values and conversion factors; General physical constants. Oct. 1963. (wallet-size plastic card). $2.50 per hundred, 5 cents each.
254. Report of the 48th National Conference on Weights and Measures 1963. Dec. 30, 1963. 75 cents.
255. Research highlights of the National Bureau of Standards, Annual Report 1963. December 1963. $1.00.
257. Microstructure of ceramic materials, proceedings of the American Ceramic Society Symposium, Pittsburgh, Pa. April 27–28, 1963, April 6, 1964. $1.75.
259. Selection of camera filters for color photography, C. S. McCamy. June 26, 1964. 5 cents.
260–1. Standard reference materials: Preparation of NBS white cast iron spectrochemical standards, R. E. Michaelis and L. L. Wyman. June 19, 1964. 30 cents.

Commercial Standards. Define quality levels for products in accordance with the principal needs of the trade. Their use is voluntary.

20–63. Vitreous china plumbing fixtures. Nov. 15, 1963. (Supersedes CS20–56). 10 cents.
150–63. Hot-rolled rail steel bars (produced from tee-section rails). Dec. 15, 1963. 10 cents.
248–64. Vinyl-Coated Glass Fiber Insect Screening and Louver Cloth. Feb. 17, 1964. 10 cents.
254–63. Acrylonitrile-butadiene-styrene (ABS) plastic pipe (SDR–PR and Class T). July 1, 1963.
255–63. Polyethylene (PE) plastic pipe (SDR–PR). July 1, 1963. 10 cents.
256–63. Polyvinyl chloride (PVC) plastic pipe (SDR–PR and Class T). July 1, 1963. 10 cents.
258–63. Expanded vinyl fabrics for apparel use. Sept. 19, 1963. 10 cents.
260–63. Shoeboard. September 10, 1963. 10 cents.
261–63. Grading of diamond powder in sub-sieve sizes. Sept. 20, 1963. 10 cents.

Simplified Practice Recommendations. List staple sizes, kinds, types, and applicable methods for certain commodities produced and stocked in greatest quantity, to aid in holding variety to a minimum. Their use is voluntary.

53–63. Steel spirals for reinforced concrete columns. Oct. 1, 1963. 10 cents.
179–63. Structural insulating board (wood or cane fiber). Dec. 31, 1963. 10 cents.
229–63. Vises (machinists' and other bench-mounted vises). Nov. 1, 1963. Supersedes R299–48. 10 cents.
265–63. Forms for two-way concrete joist floor and roof construction. Dec. 1, 1963. 5 cents.
266–63. Gypsum board products. Sept. 9, 1963. 10 cents.

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

55. Handbook of mathematical functions with formulas, graphs, and mathematical tables, edited by M. Abramowitz and I. A. Stegun. June 1964. $6.50.

Technical Note Series. This series was initiated in 1959 to supplement the Bureau's regular publications program. Technical Notes provide a means for making available scientific data that are of transient or limited interest.

18–16. Quarterly radio noise data—September, October, November 1962, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. June 10, 1963. 60 cents.
18–17. Quarterly radio noise data—December, 1962; January, February, 1963, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. May 21, 1964. 50 cents.
40–11. Mean electron density variations of the quiet ionosphere, No. 11—January 1960, J. W. Wright, L. R. Wescott, and D. J. Brown. Aug. 30, 1963. 40 cents.
40–12. Mean electron density variations of the quiet ionosphere, No. 12—February 1960, J. W. Wright, L. R. Wescott, and D. J. Brown. Dec. 6, 1963. 35 cents.
126. Mutual interference between surface and satellite communication systems—August 1, 1963, W. J. Hartman and M. T. Decker. November, 1961. 35 cents.
179. Choking two-phase flow literature summary and idealized design solutions for hydrogen, nitrogen, oxygen, and refrigerants 12 and 11, R. V. Smith. Aug. 3, 1963. 75 cents.
180. Antenna beam elevation angle for control of tropospheric interference between space system earth terminals and terrestrial stations, S. G. Lutz and W. J. Hartman. Aug. 25, 1963. 15 cents.
181. Computer program for ionospheric mapping by numerical methods, M. E. Hinds and W. B. Jones. Aug. 20, 1963. 50 cents.
182. A note on antipodal focussing, J. R. Wait. Aug. 20, 1963. 15 cents.
183. A comparison of two melting-pressure equations constrained to the triple point using data for eleven gases and three metals, R. D. Goodwin and L. A. Weber. Oct. 6, 1963. 25 cents.
184. Lunar occultations of two discrete radio sources in 1963–1964, J. A. Eddy. Oct. 11, 1963. 20 cents.
190. Impedance of commercial Leclanche dry cells and batteries, R. J. Brodd and H. J. Dewane. July 5, 1963. 40 cents.
193. A bibliography of foreign developments in machine translation and information processing, J. L. Walkowicz. July 10, 1963. $1.00.
195. Report on technical investigation of odometers, D. R. Mackay. Aug. 6, 1963. 25 cents.
196. Report of the investigation of slow-flow meters for fuel oil distribution systems, D. R. Mackay. Sept. 5, 1963. 20 cents.
197. Research on crystal growth and characterization at the National Bureau of Standards during the period January to June 1963, ed. H. S. Peiser. Sept. 23, 1963. 30 cents.
198. Photometry of projectors at the National Bureau of Standards, L. Chernoff. Dec. 17, 1963. 25 cents.
199. Correction Factor Tables For Four-Point Probe Resistivity Measurements On Thin, Circular Semiconductor Samples. Lydon J. Swartzendruber, Apr. 15, 1964. 30 cents.
200. Carbon resistors for cryogenic liquid level measurement, R. C. Muhlenhaupt and P. Smelser. Oct. 9, 1963. 25 cents.
201. A technique for extrapolating the 1 kc values of secondary capacitance standards to higher frequencies, R. N. Jones. Nov. 5, 1963. 15 cents.
202. Thermodynamic property values for gaseous and liquid carbon monoxide from 70 to 300° K with pressures to 300 atmosphere, J. G. Hust and R. B. Stewart. Nov. 30, 1963. 60 cents.
203. BOUMAC, a macro-programming system for scientific computation, J. H. Devenney and J. J. Sopka. Dec. 18, 1963. 25 cents.
204. Calculations of the field near the apex of a wedge surface, J. R. Wait and C. M. Jackson. Nov. 21, 1963. 45 cents.
205. Numerical calculations for reflection of electromagnetic waves from a lossy magnetoplasma, L. C. Walters and J. R. Wait. Nov. 21, 1963. 25 cents.
206–1. The normal phase variations of the 18 kc/s signals from NBA observed at Frankfurt, Germany, A. H. Brady, A. C. Murphy, and D. D. Crombie. Dec. 8, 1963. 25 cents.
206–2. The normal phase variations of the 18 kc/s signals from NBA observed at Maui, Hawaii, A. H. Brady, A. C. Murphy, and D. D. Crombie, Mar. 19, 1964. 25 cents.
207. Quantum field theoretic techniques and the electromagnetic properties of a uniformly magnetized electron gas, Leon A. Steinert, Apr. 6, 1964. $1.50.
208. Calculated diffraction effects at VLF from a localized ionospheric depression, James R. Wait, Jan. 16, 1964. 15 cents.
210. An atlas of solar flare effects observed on long VLF paths during 1961, C. J. Chilton, F. K. Steele, and D. D. Crombie, Mar. 13, 1964. 10 cents.
211 Vol. I. Conference on non-linear processes in the Ionosphere, December 16–17, 1963, Donald H. Menzel and Ernest K. Smith, Jr., Apr. 17, 1964. 50 cents.

211 Vol. II. Conference on non-linear processes in the ionosphere, December 16–17, 1963, Donald H. Menzel and Ernest K. Smith, Jr., Apr. 17, 1964. 45 cents.

211 Vol. III. Conference on non-linear processes in the ionosphere, December 16–17, 1963, Donald H. Menzel and Ernest K. Smith, Jr., Apr. 19, 1964. 60 cents.

211 Vol. IV. Conference on non-linear processes in the ionosphere, December 16–17, 1963, Donald H. Menzel and Ernest K. Smith, Jr., Apr. 22, 1964. 65 cents.

211 Vol. V. Conference on non-linear processes in the ionosphere, December 16–17, 1963, Donald H. Menzel and Ernest K. Smith, Jr., Apr. 24, 1964. 60 cents.

211 Vol. VI. Conference on non-linear processes in the ionosphere, December 16–17, 1963, Donald H. Menzel and Ernest K. Smith, Jr., Apr. 24, 1964. 60 cents.

214. Absolute photometry of the light of the night sky. The zenith intensity of Haleakala (latitude N 20.7°) and at Fritz Peak (latitude N 39.9°), F. E. Roach and L. L. Smith. June 29, 1964. 35 cents.

215. Percentage points of the beta distribution, L. E. Vogler, May 30, 1964. 25 cents.

216. Computation of Hankel functions, Leslie A. Berry, June 12, 1964. 20 cents.

217. A bibliography of thermophysical properties of argon from 0 to 300 °K. L. A. Hall, J. G. Hust, and A. L. Gosman, June 12, 1964. 55 cents.

231. Solar heating, radiative cooling, and thermal movement—their effects on built-up roofing, W. C. Cullen. Dec. 16, 1963. 25 cents.

233. Sensitivity indices for Hall generators, S. Rubin and G. J. Rogers. Feb. 6, 1964. 20 cents.

234. Soviet research in field emission, 1960–63; an annotated bibilography, T. W. Marton and R. Klein. Feb. 24, 1964. 30 cents.

235. A portable rubidium-vapor frequency standard, R. J. Carpenter. April 6, 1964. 25 cents.

236. Research on crystal growth and characterization at the NBS, July to Dec. 1963, edited by H. S. Peiser. April 6, 1964. 40 cents.

237. Disclosures on various subject: A frequency meter, a phase shifter, a double-tuned transformer, and a ram-controlled system. April 10, 1964. 15 cents.

238. Miscellaneous studies in probability and statistics: distribution theory, small-sample problems, and occasional tables, Statistical Engineering Laboratory. April 24, 1964. 20 cents.

240. Average power dissipated in a diode swept along its reverse characteristic, H. A. Schafft. 20 cents.

241. Calculations for comparing two-point and four-point probe resistivity measurements on rectangular bar-shaped semiconductor samples, L. J. Swartzendruber. 25 cents.

242. A Fortran program for analysis of ellipsometer measurements and calculation of reflection coefficients from thin films, F. L. McCrackin. 30 cents.

243. Survey of multiple charged ions, F. L. Mohler. May 27, 1964. 10 cents.

Publications in Outside Journals*

Abramowitz, S., Broida, H. P., ν_3 vibration in condensed oxygen, nitrogen, and argon, J. Chem. Phys. **39**, No. 9, 2383–2384 (Nov. 1, 1964).

Agy, V., Davies, K., Effects of magnetic disturbance as noted on oblique incidence ionograms, AGARDograph 59, The Effect of Disturbances of Solar Origin on Communications, ed. G. J. Gassmann, pp. 167–176 (Pergamon Press Inc., London, England, 1963).

Akima, H., Signal-to-noise characteristics of some typical systems and their comparisons, Proc. Mountain States Navy Research and Development Clinic, Raton, N. Mex., Sept. 28–29, 1961, pp. A125–A130 (Raton, Communication and Electronics Foundation, 1963).

Akima, H., The error rate in a multiple frequency shift system and the output signal noise ratio in a frequency modulation and pulse code modulation frequency shift system, Proc. IEE (London) **III**, No. 3, 547–555 (Mar. 1964).

Akima, H., Theoretical studies on signal-to-noise characteristics of an FM system, IEE Trans. Space Electron. Telemetry **SET–9**, No. 4, 101–108 (Dec. 1963).

Allen, C. W., Corliss, C. H., Absolute scale of oscillator strengths, Monthly Notices Roy. Astron. Soc. **126**, No. 1, 37–40 (1963).

Allen, H. C., Jr., Kokoszka, G. F., Inskeep. R. G., The electron paramagnetic resonance spectrum of some tris-complexes of copper (II), J. Am. Chem. Soc. **86**, 1023–1025 (1964).

*For completeness, a few references to publications issued prior to July 1963 are included.

Alt, F. L., Rhodes, I., Recognition of clauses in machine translation of languages, Proc. Intern. Conf. Machine Translation of Languages and Applied Language Analysis, Teddington, England, Symp. No. 13, pp. 126–142 (Her Majesty's Stationery Office, London, England, 1961).

Ambler, E., Dove, R. B., Kaeser, R. S., A He^3 cryostat for performing experiments with oriented nuclei (Proc. 1962 Cryogenic Engineering Conf.), Book, Advances in Cryogenic Engineering 8, Paper H–2, 443–445 (Plenum Press, Inc., New York, N.Y., 1963).

Andersen, H. C., Oppenheim, I., Shuler, K. E., Exact conditions for the preservation of a canonical distribution in a Markovian relaxation process, J. Math. Phys. **5**, 522–536 (Apr. 1964).

Andersen, K., Shuler, K. E., On the relaxation of the hard sphere Rayleigh and Lorentz gas, J. Chem. Phys. **40**, 633 (Feb. 1, 1964).

Antonucci, J. M, Synthesis of perfluorostyrene and (2,2-difluorovinyl) perfluorobenzene (α-hydroheptafluorostyrene). A general method for the synthesis of highly fluorinated styrenes, SPE Trans. **3**, No. 3, 225–230 (July 1963).

Armstrong, G. T., Calorimetry (report on Calorimetry Conf.), Science **143**, No. 3602, 158–163 (Jan. 10, 1963); Phys. Today **17**, No. 2, 50–54 (Feb. 1964).

Armstrong, G. T., The calorimeter and its influence in the development of chemistry, J. Chem. Ed. **41**, No. 6, 297–307 (June 1964).

Armstrong, G. T., Vapour pressure, Encyclopaedic Dictionary of Physics 7, 586–587 (Pergamon Press Inc., New York, N.Y., 1962).

Arni, H. T., Discussion of paper on "Predicting compressive strength from the properties of the fresh concrete," Mater. Res. Std. **4**, No. 6, 296–297 (June 1964).

Ausloos, P., Gorden, R., Jr., Lias, S. G., Effect of pressure in the radiolysis and photolysis of methane J. Chem. Phys. **40**, No. 7, 1854–1860 (Apr. 1964).

Ausloos, P., Lias, S. G., Gorden, R., Jr., Effect of additives on the ionic reaction mechanism in the radiolysis of methane, J. Chem. Phys. **39**, No. 12, 3341–3348 (Feb. 1964).

Ausloos, P., Lias, S. G., Sandoval, I. B., The gas phase radiolysis of propane. The effect of pressure and added inert gases, Discussions Faraday Soc. No. **36**, 66–74 (Mar. 1964).

Auterman, J. L., Remarks presented at panel discussion on modulation, Proc. Mountain States Navy Research and Development Clinic, Raton, N. Mex., Sept. 28–29, 1961, pp. A131–A132 (Raton, Communications and Electronics Foundation, 1963).

Bailey, D. K., Polar-cap absorption, Planetary Space Sci. **12**, 495–541 (May 1964).

Baird, R. C., Fresnel zone diffraction effects at 50 Gc/sec. Determined from measured aperture field data, Program and Digest 1963 IEEE Prof. Group Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 171–173 (1963).

Balsley, N. B., Evidence of a stratified echoing region at 150 km in the vicinity of the magnetic equator during daylight hours, J. Geophys. Res. **69**, No. 9, 1925–1930 (May 1964).

Bardwell, G. E., Crow, E. L., A two-parameter family of hyper-Poisson distributions, J. Am. Statist. Assoc. **59**, No. 305, 133–141 (Mar. 1964).

Barghausen, A., Jacobs, G., Lillie, D., HF propagation characteristics in equatorial latitudes, Program and Digest of 1963 IEEE Prof. Group. Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 37–42 (1963).

Barnes, J. A., Fey, R. L., Synchronization of two remote atomic time scales, Proc. IEEE **51**, No. 11, 1665 (Nov. 1963).

Barrows, E. C., Correlation matrix for radio waves in the troposphere (Proc. Symp. Electromagnetic Theory and Antennas, Copenhagen, 1963), Monograph, Electromagnetic Theory and Antennas 2, Sec. C, 743–746 (Macmillan and Co., Ltd., London, England, 1963).

Barrows, E. C., Phase instability in a tropospheric relay link, Program and Digest 1963 IEEE Prof. Group. Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 52–55 (1963).

Barrows, E. C., Residual range and range rate errors due to the troposphere, Proc. Conf. Tropospheric Refraction (Dec. 1963).

Barsis, A. P., Norton, K. A., Rice, P. L., Predicting the performance of tropospheric communication links singly and in tandem, Proc. Mountain States Navy Research and Development Clinic, Raton, N. Mex., Sept. 28–29, 1961, pp. A71–A104 (Raton, Communications and Electronics Foundation, 1963).

Bass, A. M., The absorption spectrum of the "pink" afterglow of nitrogen in the vacuum ultraviolet, J. Chem. Phys. **40**, No. 3, 695–700 (Feb. 1, 1964).

Bass, A. M., Broida, H. P., Vacuum ultraviolet absorption spectra of oxygen in liquid and crystalline argon and nitrogen, J. Mol. Spectry, **12**, No. 3, 221–230 (Mar. 1964).

Bass, A. M., Garvin, D., On the concentrations of vibrationally excited O_2 formed in the flash photolysis of NO_2, J. Chem. Phys. (Letter) **40**, No. 6, 1772–1773 (Mar. 15, 1964).

Bass, A. M., Keubler, N. A., Nelson, L. S., Observation of FeO in absorption by flash heating and kinetic spectroscopy, J. Chem. Phys. (Note) **40**, No. 10, 3121 (May 15, 1964).

Bates, R. G., Determination of *p*H, Theory and Practice, book, 450 pages (John Wiley & Sons, Inc., New York, N.Y., Feb. 1964).

Bates, R. G., Paabo, M., Robinson, R. A., Interpretation of *p*H measurements in alcohol-water solvents, J. Phys. Chem. **67**, No. 9, 1833–1838 (Sept. 1963).

Bay, Z., Farago, P. S., Remarks on coincidence experiments with visible light, Proc. Roy. Soc. Edinburgh, Sec. A. Math. and Phys. Sci. **LXVI**, Pt. 11, No. 10, 111–115 (Royal Society of Edinburgh, Edinburgh, Scotland, 1963).

Bay, Z., Pearlstein, R. M., A theory of energy transfer in the photosynthetic unit, Proc. Natl. Acad. Sci. **50**, No. 6, 1071–1078 (Dec. 1963).

Bay, Z., Pearlstein, R. M., Delocalized versus localized pictures in resonance energy transfer, Proc. Natl. Acad. Sci. **50**, No. 5, 962–967 (Nov. 1963).

Bean, B. R., The radio thermal noise properties of the lower atmosphere, Program and Digest 1963 IEEE Prof. Group. Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 30–31 (1963).

Bean, B. R., Tropospheric refraction and attenuation of radio waves, book. Advances of Radio Research, pp. 53–155 (Academic Press, Inc., New York, N.Y., June 1964).

Bean, B. R., Dutton, E. J., Frank, V. R., Lane, J. A., Sweezy, W. B., A radio-meteorological study, Program and Digest 1963 IEEE Prof. Group. Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 56–60 (1963).

Bean, B. R., McGavin, R. E., The turbulent characteristics of the radio refractive index near the ground, Program and Digest 1963 IEEE Prof. Group. Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 60–64 (1963).

Beatty, R. W., A differential microwave phase shifter, IEEE Trans. Microwave Theory Tech. **MTT–12**, No. 2, 250–251 (Mar. 1964).

Beatty, R. W., Editorial, IEE Trans. Microwave Theory Tech. **MTT–12**, No. 3, 274 (May 1964).

Beatty, R. W., Insertion loss concepts, Proc. IEEE **52**, No. 6, 663–671 (June 1964).

Beatty, R. W., Measuring the directivity of a directional coupler using a sliding short-circuit and an adjustable sliding termination, IEEE Trans. Microwave Theory Tech. **MTT–12**, No. 3, 283 (May 1964).

Beatty, R. W., Microwave standards and measurements, a progress review 1960–1963, IEEE Trans. Instr. Meas. **IM–12**, No. 3, 134–138 (Dec. 1963).

Beatty, R. W., Standards and measurement of attenuation, impedance and phase shift, Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, XIII, 80–92 (1964).

Beatty, R. W., Kerns, D. M., Relationships between different kinds of network parameters, not assuming reciprocity or equality of the waveguide or transmission line characteristic impedances, Proc. IEEE **52**, No. 1, 84 (Jan. 1964).

Beaty, E. C., Patterson, P. L., Reaction rates for the formation of He_2^+ and Ne_2^+, Book, Compt. Rend. VI^e Conf. Intern. sur les Phenomenes D'Ionisation dans les Gaz, ed. P. Hubert and E. Cremieu-Alcan **III**, 289–293 (S.E.R.M.A., Publ. Co., Paris, France, 1963).

Beck, D. R., Kreith, F., Kropschot, R. H., A new steady-state calorimeter for measuring heat transfer through cryogenic insulation (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering 9, Paper B–4, 64–70 (Plenum Press, Inc., New York, N.Y., 1964).

Beehler, R. E., Glaze, D. J., Experimental evaluation of a thallium beam frequency standard, Proc. 17th Annual Frequency Control Symp. (1963).

Bender, P. L., Effect of hydrogen-hydrogen exchange collisions, Phys. Rev. **132**, No. 5, 2154–2158 (Dec. 1, 1963).

Bender, P. L., Interpretation of frequency shifts due to electron exchange collisions, Phys. Rev. **134**, No. 5A, A1174–A1180 (June 1, 1964).

Bender, P. L., Optically pumped magnetometers and related experiments in high magnetic fields, Book, Quantum Electronics III, ed. P. Grivet and N. Bloembergen, I, 263–273 (Columbia Univ. Press, New York, N.Y., 1964).

Bennett, J. A., Evidence regarding the mechanism of fatigue from studies of environmental effects, Acta Met. **11**, No. 7, 799–800 (July 1963).

Bennett, L. H., Snodgrass, R. J., Absence of pronounced quadrupole effects in the nuclear resonance of In^{115} in a non-cubic environment, Phys. Rev. **134**, No. 5A, A1290 (June 1, 1964).

Berendt, R. D., Impact noise in multifamily dwellings, Bldg. Res. **1**, No. 1, 40–42 (Jan.-Feb. 1964).

Berendt, R. D., Schmidt, H. A., Jr., A portable impedance tube, J. Acoust. Soc. Am. **35**, No. 7, 1049–1052 (July 1963).

Berg, H. F., Eckerle, K. L., Burris, R. W., Wiese, W. L., Relative oscillator strengths of some O II and O III lines from measurements on shock-heated plasmas, Astrophys. J. **139**, No. 2, 751–757 (Feb. 15, 1964).

Berger, M. J., Seltzer, S. M., Energy spectra and angular distributions of electrons transmitted through sapphire (Al_2O_3) foils, NASA Spec. Publ. SP3008, pp. 1–107 (Mar. 1964).

Berger, R. T., Herzfeld, C. M., On the nature of the crystal field approximation. II. Numerical results, J. Chem. Phys. **39**, No. 4, 1122–1126 (Aug. 15, 1963).

Berman, H. A., Newman, E. S., Calorimetry of portland cement: I. Effect of various procedures on the determination of heat of solution, ASTM Proc. **63**, 830–851 (1963).

Bernstein, B., Kearsley, E. S., Zapas, L. J., A study of stress relaxation with finite strain, Trans. Soc. Rheology **VII**, 391–410 (1963).

Bestul, A. B., Change, S. S., Excess entropy at glass transformation, J. Chem. Phys. **40**, 3731 (1964).

Bienstock, A., Burley, G., Thermal expansion of silver iodide, J. Phys. Chem. Solids **24**, 1271–1278 (Apr. 1963).

Billick, I. H., Exact Faxen solution for centrifugation when sedimentation depends linearly on concentration, Nature **201**, No. 4922, 912–913 (Feb. 1964).

Blatt, J. M., Lyness, J. N., Larsen, S. Y., Three body bound state in He^4, Phys. Rev. **131**, No. 5, 2131–2132 (Sept. 1963).

Block, S., Molin, J., Piermarini, J., X-ray study of a cadmium borate glass, J. Am. Ceram. Soc. **46**, 557 (1963).

Block, S., Perloff, A., The direct determination of the crystal structure of $NaB(OH)_4 \cdot 2H_2O$, Acta Cryst. **16**, 1233–1238 (Dec. 1963).

Block, S., Perloff, A., Weir, C. E., The crystallography of some M^{2+} borates, Acta Cryst. **17**, 314–315 (Mar. 1964).

Bolton, E. C., Magnetic tape recording and reproducing of atmospheric noise with a wide dynamic range, Rev. Sci. Instr. **35**, No. 3, 377–380 (Mar. 1964).

Bonanomi, J., Kartaschoff, P., Newman, L. J., Atkinson, W. R., A comparison of the TA_1 and the NBS–A atomic time scales, Proc. IEEE **52**, No. 4, 439 (Apr. 1964).

Borkowski, R. P., Ausloos, P. J., Gas-phase radiolysis of *n*-butane, J. Chem. Phys. **39**, No. 3, 818–824 (Oct. 1963).

Borkowski, R. P., Ausloos, P., Hydride and proton transfer reactions involving *sec*-propyl ions, J. Chem. Phys. **40**, No. 4, 1128–1132 (Feb. 1964).

Boublil, Y., Earnshaw, K. B., Propagation of a reflected shock wave in a transverse magnetic field, Phys. Fluids **7**, No. 6, 876–881 (June 1964).

Bower, V. E., Robinson, R. A., Isopiestic vapor pressure measurements of the ternary system: sorbitol-sodium chloride-water at 25°, J. Phys. Chem. **67**, No. 7, 1540–1541 (July 1963).

Bower, R. W., Robinson, R. A., Osmotic and activity coefficients of tetraethylammonium iodide in aqueous solution at 25°, Trans. Faraday Soc. **59**, 1717–1719 (Aug. 1963).

Bower, V. E., Robinson, R. A., The thermodynamics of the ternary system: urea-sodium chloride-water at 25°, J. Phys. Chem. **67**, No. 7, 1524–1527 (July 1963).

Bowles, K. L., Equatorial electron density profiles to 5000 kms, using the incoherent scatter technique (Proc. 3d Intern. Space Science Symp.), book, Space Research **III**, 253–264 (1962).

Bowles, K. L., Radiowave scattering in the ionosphere, Advan. Electronics and Electron Phys. **19**, 55–176 (1963).

Bowles, K. L., The association of plane-wave electron-density irregularities with the equatorial electrojet, J. Geophys. Res. **68**, No. 9, 2503–2525 (May 1, 1963).

Brady, A. H., Crombie, D. D., Studying the lunar tidal variations in the *D* region of the ionosphere by means of a very-low-frequency phase observation, J Geophys. Rev. **68**, No. 19, 5437–5442 (Oct. 1, 1963).

Brady, A. H., Crombie, D. D., Jean, A. G., Murphy, A. C., Steele, F. K., Long lived effects in the *D* region after the high-altitude nuclear explosion of July 9, 1962, J. Geophys. Res. **69**, No. 9, 1921–1924 (May 1, 1964).

Bramble, J. H., Payne, L. E., Pointwise bounds in the first biharmonic boundary value problem, J. Math. Phys. **42**, No. 4, 278–286 (Dec. 1963).

Branscomb, L. M., A review of photodetachment and related negative ion processes relevant to aeronomy, Ann. Geophys. **20**, No. 1, 88–105 (Jan.–Mar. 1964).

Branscomb, L. M., Observatory report—Joint Institute for Laboratory Astrophysics, Astron. J. **68**, No. 9, 660–662 (Nov. 1963).

Branscomb, L. M., The present and future of astrophysics and its effects on industry in Colorado (Proc. University-Industry Liaison Conf., 1963), book, Colorado and the New Technological Revolution, ed. W. H. Miernyk, pp. 55–64 (Bureau of Economic Research, Univ. Colorado, Boulder, Colo., 1964).

Braut, A. O., A symmetry group containing both the Lorentz Group and SU_3, Il Nuovo Cimento **32**, 234–236 (Apr. 1964).

Brennan, J. A., A preliminary study of the orifice flow characteristics of liquid nitrogen and liquid hydrogen discharging into a vacuum (Proc. 1963 Cryogenic Eng. Conf. Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), book, Advances in Cryogenic Engineering **9**, Paper E–6, 292–303 (Plenum Press, Inc., New York, N.Y., 1964).

Brenner, A., Electroless plating, Mod. Electroplating, pp. 698–713 (1963).

Brentari, E. F. G., Smith, R. V., Medical applications, ASHRAE Guide and Data Book, Ch. 68, pp. 773–778 (Am. Soc. Heating, Refrig. Air Conditioning Engrs., Inc., New York, N.Y., 1964).

Broadhurst M. G., Q meter measurements up to 260 MHz (Proc. Conf. Electric Insulation), 1963 Annual Report Natl. Acad. Sci.-Natl. Res. Council Publ. 1141, pp. 77–80 (1963).

Brodd, R. J., DeWane, H. J., Impedance of Leclanche cells and batteries, J. Electrochem. Soc. **110**, No. 11, 1091–1097 (Nov. 1963).

Brown D. W., Wall, L. A., Radiation-induced polymerization of high pressure of *n*-tetradecafluroheptene-1; 1,1,2-trifluorovinyl phenyl ether; and 1,2,3,4,5-pentafluorophenyl 1,1,2-trifluorovinyl ether SPE Trans. **3**, No. 4, 300–308 (Oct. 1963).

Brown, J. E., Tryon, M., Mandel, J., Determination of propylene in ethylene-propylene copolymers in infrared spectroscopy, Anal. Chem. **35**, No. 13, 2172–2176 (Dec. 1963).

Burgeson D. A., Pestalozzi, W. G., Richards, R. J., The performance of point level sensors in liquid hydrogen (Proc. 1963 Eng. Conf. Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), book, Advances in Cryogenic Engineering 9, Paper G–5, 416–422 (Plenum Press, Inc., New York, N.Y., 1964).

Burley, G., An X-ray determination of the Debye temperature of silver iodide, J. Phys. Chem. Solids **25**, 629 (1964).

Burley, G., Kinetics and mechanism of the low-cubic to hexagonal phase transformation of silver iodide, J. Phys. Chem. **68**, No. 5, 1111–1113 (1964).

Burley, G., Polymorphism of silver iodide, Am. Mineralogist **48**, 1266–1276 (Nov.-Dec. 1963).

Burnes, G. W., Studies at NBS of the platinum-6% rhodium vs. platinum-30% rhodium thermocouple—a preliminary report (Proc. SAE Meeting, Los Angeles, Calif., Sept. 23–27, 1963), SAE Preprint No. 750B (1963).

Calvert, W., Goe, G. B., Plasma resonances in the upper ionosphere, J. Geophys. Res. **68**, No. 22, 6113–6120 (Nov. 15, 1963).

Calvert, W., Rishbeth, H., VanZandt, T. E., Alouette ionic magnetic-field and plasma studies, IG Bull. No. 83, pp. 16–19 (May 1964); Trans. AGU **45**, No. 2, 398–401 (June 1964).

Calvert, W., Schmid, C. W., Spread-F observations by the alouette topside sounder satellite, J. Geophys. Res. **69**, No. 9, 1839–1852 (May 1, 1964).

Campbell, W. H., A study of geomagnetic effects associated with auroral zone electron precipitation observed by balloons, J. Geomagn. Geoelec. **11**, No. 1, 37–57 (June 1964).

Campbell, W. H., Studies in the geomagnetic micropulsation frequency range, IEEE Intern. Conv. Record **11**, Pt. 9, 25–28 (Mar. 25–28, 1963).

Campbell, W. H., Young, J. M., Auroral-zone observations of infrasonic pressure waves related to ionospheric disturbances and geomagnetic activity, J. Geophys. Res. **68**, No. 21, 5909–5916 (Nov. 1963).

Cargo, G. T., Shisha, O., Zeros of polynomials and fractional order differences of their coefficients, J. Math. Anal. Appl. **7**, No. 2, 176–182 (Oct. 1963).

Carrington, T., Spectroscopic investigations of fluorescence and chemiluminescence in gasses (Collection of papers), Aero-Space Research Laboratory Report No. 64–51 (Mar. 1964).

Case, W. E., Larsen, N. T., Klystron protection circuit, Rev. Sci. Instr. **34**, No. 7, 809–810 (July 1963).

Caswell, R. S., Beverly, W. B., Spiegel, V., Jr., Energy dependence of proportional-counter fast-neutron dosimeters (Proc. Symp. Neutron Detection, Dosimetry and Standardization, Atomic Energy Agency, Atomic Energy Research Establishment, Harwell, England, Dec. 10–14, 1962), book, Neutron Dosimetry **II**, 227–237 (Intern. Atomic Energy Agency, Vienna, July 1963).

Caswell, R. S., Noyce, R. H. Garfinkle, S. B., Mosburg, E. R., Jr., Recent developments in neutron source standardization (Proc. Symp. Neutron Detection, Dosimetry and Standardization, International Atomic Energy Agency, Atomic Energy Research Establishment, Harwell, England, Dec. 10–14, 1962), book, Neutron Dosimetry **II**, 547–555 (International Atomic Energy Agency, Vienna, July 1963).

Cataland, G., Plumb, H. H., Absolute temperatures determined from measurements of the velocity of sound in helium gas, Proc. Advisory Committee on Thermometry to the Intern. Bureau of Weights and Measures, 6th Session, p. 175 (Sept. 26–27, 1962).

Caul, H. J., Longton, R., Sweeney, W. T., Paffenbarger, G. C., Effect of rate of loading, time of trituration and test temperature on compressive strength of dental amalgam, J. Am. Dental Assoc. **67**, No. 5, 670–678 (Nov. 1963).

Chamberlain, G. E., Smith, S. J., Heddle, D. W. O., The excitation of the 2P state of hydrogen by electrons of near-threshold energy, Phys. Rev. Letters **12**, No. 23, 647–649 (June 8, 1964).

Chilton, C. J., Crombie, D. D., Jean, A. G., Phase variations in V. L F. propagation, AGARDograph 74, Propagation of Radio Waves at Frequencies Below 300 Kilocycles, ch. 19, pp. 257–290 (Pergamon Press Inc., New York, N.Y., 1964).

Chilton, C. J., Diede, A., Radicella, S., Transequatorial reception of a very-low-frequency transmission, J. Geophys. Res. **69**, No. 7, 1319–1328 (Apr. 1, 1964).

Chilton, C., Steele, F. K., Norton, R. B., Very-low-frequency phase observations of solar flare ionization in the *D* region of the ionosphere, J. Geophys. Res. **68**, No. 19, 5421–5435 (Oct. 1, 1963).

Chin, J., Hirshfeld, A. T., Hoppes, D. D., Solid state detectors for beta-ray spectroscopy below 4.2°K, Rev. Sci. Instr. **34**, No. 12, 1258–1259 (Nov. 1963).

Chivers, H. J. A., Radio star scintillations and spread-F echoes, J. Atmospheric and Terrest. Phys. **25**, No. 8, 468–473 (Aug. 1963).

Chivers, H. J. A., Hargreaves, J. K., Ionospheric absorption in conjugate regions and possible oscillation of the ionosphere, Nature **202**, 891–893 (May 30, 1964).

Civjan, S., Brauer, G. M., Physical properties of cements, based on zinc oxide hydrogenated rosin, *o*-ethoxybenzoic acid and eugenol, J. Dental Res. **43**, No. 2, 281–299 (Mar.–Apr. 1964).

Clark, T. A., Electronic scanning for large radiotelescopes, Program and Digest 1963 IEEE Prof. Group Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 242–246 (July 1963).

Coblentz, C. W., Achenbach, P. R., Field measurements of air infiltration in ten electrically-heated houses, ASHRAE J. **5**, No. 7, 69 (July 1963).

Codling, K., Madden, R. P., Optically observed inner shell electron excitation in neutral Kr and Xe, Phys. Rev. Letters **12**, No. 4, 106–107 (Jan. 1964).

Cohen, A., Tipson, R. S., Some derivatives of 2,2′(phenylimino)diethanol, J. Med. Chem. **6**, 822–824 (Nov. 1963).

Coleman, B. D., Gornick, F., Weiss, G., Statistics of irreversible termination in homogeneous anionic polymerization, J. Chem. Phys. **39**, No. 12, 3233–3239 (Dec. 1963).

Collett, C. T., Theory of operation of the rotary positive displacement meter (Proc. 23d Annual Gas Measurement Short Course, Aug. 20, 1963), West Virginia Univ. Tech. Bull. **70**, pp. 48–53 (1963).

Cones, H. N., Some impulse sparkover voltages for a 200 cm sphere gap, IEEE Component Parts Conf., Paper No. CP63–929 (June 1963).

Cooper, J. W., The calculations of autoionization probabilities, (Proc. 3d Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963), book, Atomic Collision Processes, ed. M. R. C. McDowell, pp. 595–599 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Cooper, J. W., Martin, J. B., Correlation effects in two- and three-electron systems, Phys. Rev. **131**, No. 3, 1183–1186 (Aug. 1, 1963).

Corliss, C. H., Warner, B., Absolute oscillator strengths for Fe I, Astrophys. J. Suppl. Series No. 83, **VIII**, 395–438 (Feb. 1964).

Corruccini, R. J., Solubility of helium in liquid hydrogen, J. Chem. Phys. **40**, 2039–2040 (Apr. 1964).

Corruccini, R. J., Thermal radiation properties of solids at low temperatures (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1963), NASA Spec. Publ. SP–31, Session II, Paper 4, p. 33 (Dec. 1963).

Cottony, H. V., Current development in an electronically scanned antenna, Proc. Symp. Electromagnetic Theory and Antennas, Copenhagen, June 25–30, 1962, pp. 1289–1294 (Pergamon Press, London, England, 1963).

Couch, D. E., The electrolysis of formamides, acetamides and propionamides, Electrochim. Acta **9**, No. 4, 327–336 (Apr. 1964).

Coyle, T. D., Ritter, J. J., Farrar, T. C., Preparation and properties of difluoroborane, Proc. Chem. Soc., p. 25 (Jan. 1964).

Coyle, T. D., Stone, F. G. A., Some aspects of the coordination chemistry of boron, Progr. Boron Chem. **1**, 83–166 (1964).

Crichlow, W. Q., Noise in VLF to HF bands and prediction of communication reliability, Proc. Mountain States Navy Research and Development Clinic, Raton, N. Mex., Sept. 28–29, 1961, pp. A67–A70 (Raton, Communications and Elctronics Foundation, 1963).

Crombie, D. D., Very-low-frequency radio waves and the ionosphere, Science **142**, No. 3591, 508–510 (Oct. 25, 1963).

Crombie, D. D., Jean, A. G., The guided propagation of ELF and VLF radio waves between the earth and the ionosphere, Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, **XIII**, 195–206 (1964).

Crombie, D. D., McNeill, F. A., Allcock, G. M., Variations in phase path of man-made one-hop whistler mode signals at 18.6 kilocycles per second, J. Geophys. Res. **68**, No. 23, 6229–6235 (Dec. 1, 1963).

Crow, E. L., Accumulation of calibration errors and their optimum distribution, Trans. Am. Soc. Quality Control 18th Midwest Conf., Tulsa, Okla., pp. 86–100 (Oct. 1963).

Cullen, W. C., Appleton, W. H., Effect of insulation on the weathering of smooth-surfaced, built-up roofs exposed to solar heating, Construction Specifier Mag. **16**, No. 5, 35–38 (Oct. 1963).

Currie, C. L., Okabe, H., McNesby, Jr., Vacuum ultraviolet photochemistry. VI. Photolysis of cyclopropane with the xenon resonance lines, J. Phys. Chem. **67**, No. 7, 1494–1497 (Aug. 1963).

Cuthill, Jr., Wyman, L. L., Yakowitz, H., Metallurgical microanalysis with the electron probe, J. Metals **15**, No. 10, 736–768 (Oct. 1963).

Cutkosky, R. D., Four-terminal-pair networks as precision admittance and impedance standards, IEEE Trans. Commun. Elec. **CE–70**, 19–22 (Jan. 1964).

Dalke, J. L., Problems and prospects in electrical properties of materials, Proc. Mountain States Navy Research and Development Clinic, Raton, N. Mex., Sept. 28–29, 1961, pp. D7–D14 (Raton, Communications and Electronics Foundation, 1963).

Danos, M., Greiner, W., The λ-absorption cross section of holmium in the dynamic collective theory, Physics Letters **8**, No. 2, 113–115 (Jan. 15, 1964).

Datta, S. P., Grzybowski, A. K., Bates, R. G., Second acid dissociation of N,N-Di-(2-hydroxyethyl)-glycine and related thermodynamic quantities from 0 to 55°, J. Phys. Chem. **68**, No. 2, 275–280 (Feb. 1964).

Davis, M. Gilmore, B., Freis, E., Improved transducer for external recording of arterial pulse waves, IEEE Trans. Bio-Med. Elec. **BME–10**, No. 4, 173–175 (Oct. 1963).

Deitz, V. R., Carpenter, F. G., Cane sugar refining. II. Decolorization with adsorbents, Cane Sugar Handb., ed. G. P. Meade, 9th ed., pp. 342–385 (John Wiley & Sons, Inc., New York, N.Y., Aug. 1963).

Deitz, V. R., Carpenter, F. G., Special techniques for use in sugar analysis, Cane Sugar Handb., ed. G. P. Meade, 9th ed., pp. 605–619 (John Wiley & Sons, Inc., New York, N.Y., Aug. 1963).

Deitz, V. R., McFarlane, E. F., Hydrogen reaction with carbon and nickel evaporated films, Carbon **1**, 117–125 (1964).

Deitz, V. R., Rootare, H. M., Carpenter, F. G., The surface composition of hydroxylapatite derived from solutions behavior of aqueous suspensions, J. Colloid Sci. **19**, No. 1, 87–101 (Jan. 1964).

Denison, A. B., James, L. W., Currin, J. D., Tanttila, W. H., Mahler, R. J., Ultrasonically induced nuclear spin transitions in antiferromagnetic $KMnF_3$, Phys. Rev. Letters **12**, No. 10, 244–245 (1964).

Desch, R. F., Larson, R. E., Bolometric microwave power calibration techniques at the National Bureau of Standards, IEEE Trans. Instr. Meas. **IM–12**, No. 1, 29–33 (June 1963).

DeSouza, P. D., Snow, G. A., Meshkov, S., S-wave hyperon-nucleon interactions and SU_3 symmetry, Phys. Rev. **135**, 565 (1964).

deWit, R., On the growth of helical dislocations, Trans. AIME **227**, 1443–1452 (Dec. 1963).

Dhumwad, R. K., Bass, A. M., A low pressure arc source for the emission spectrum of the FeO molecule, Appl. Opt. **2**, No. 12, 1335 (Dec. 1963).

Dibeler, V. H., Reese, R. M., Mass spectrometric study of the photoionization of acetylene and acetylene-d_2, J. Chem. Phys. **40**, No. 7, 2034–2035 (Apr. 1, 1964).

Dibeler, V. H., Rosenstock, H. M., Mass spectra and metastable transitions of H_2S, HDS and D_2S, J Chem. Phys. **39**, No. 11, 3106 (Dec. 1, 1963).

Dibeler, V. H., Rosenstock, H. M., Metastable transitions in mass spectra of methane and the deuteromethanes, J. Chem. Phys. **39**, 1326 (1963).

Dodge, W. R., Domen, S. R., Hirshfeld, A. T., Hoppes, D. D., Anomaly in response of semi-conductor detector at low temperature, IEEE Trans. Nucl. Sci. **NS–11**, 1–14 (June 1964).

Dougherty, J. P., Farley, D. T., Jr., A theory of incoherent scattering of radiowaves by a plasma. 3. Scattering in a partly ionized gas, J. Geophys. Res. **68**, No. 19, 5473–5486 (Oct. 1, 1963).

Dougherty, R. H., Oblique incidence pulse measurement at 100 kc, AGARDograph 74, Propagation of Radio Waves at Frequencies Below 300 Kilocycles, pp. 133–148 (Pergamon Press, Inc., New York, N.Y., 1963).

Douglas, T. B., Statistical model for the beta zirconium hydrides, J. Chem. Phys. **40**, No. 8, 2248–2257 (Apr. 15, 1964).

Dunn, G. H., Studies of photodissociation of molecular ions, (Proc. 3d Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963), Book, Atomic Collision Processes, ed. M. R. C. McDowell, pp. 997–1005 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Dunn, G. H., Kieffer, L. J., Dissociative ionization of H_2: a study of angular distributions and energy distributions of resultant fast protons, Phys. Rev. **132**, No. 5, 2109–2117 (Dec. 1, 1963).

Ecklund, W. L., A low input VSWR coaxial diode switch for the UHF band, IEEE Trans. Microwave Theory Tech. (Corres. Sec.) **MTT–12**, No. 3, 359 (May 1964).

Ehrlich, M., Use of photographic film for personnel dosimetry; basic physical considerations, Symp. Personnel Dosimetry Techniques for External Radiation, Apr. 1–5, 1963, Madrid, Spain, pp. 49–74 (Apr.–Dec. 1963).

Ehrlich, M., McLaughlin, Wm. L., Zeitler, E., Rate dependence in a solarizing commercial x-ray emulsion: sensitometric properties, number, and structure of developed grains, J. Opt. Soc. Am. **54**, No. 2, 176–183 (Feb. 1964).

Eisenhart, C., The meaning of "least" in least squares, J. Walsh. Acad. Sci. **54**, No. 2, 24–33 (Feb. 1964).

Eisenhauer, C., Some results on the energy-dependent Milne problem for light gases, Nucl. Sci. Eng. **19**, 95–101 (May 1964).

Eisenstein, J. C., Spectrum of Er^{3+} in $LaCl_3$ J. Chem. Phys. **39**, No. 9, 2128–2133 (Nov. 1, 1963).

Eisenstein, J. C., Spectrum of Nd^{3+} in $LaCl_3$, J. Chem. Phys. **39**, No. 9, 2134–2140 (Nov. 1, 1963).

Eisenstein, J. C., The validity of crystal field theory as applied to rare earth ions: an analysis of the spectrum of praseodymium trichloride, Proc. 1st Intern. Conf. Paramagnetic Resonance, Israel, I, Pt. II, 253–259 (Academic Press, Inc., New York, N.Y., 1963).

Eicke, W. G., Jr., The operating characteristics of Zener reference diodes and their measurements, ISA Trans. **3**, No. 2, 93–99 (Apr. 1964).

Engen, G. F., RF and microwave power measurements, Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, **XIII**, 77–80 (1964).

Eriksen, K. W., Gillmor, C. S., Hargreaves, J. K., Some observations of short-duration cosmic noise absorption events in conjugate regions at high magnetic latitude, J. Atmospheric Terrest Phys. **26**, 77–90 (1964).

Erminy, D., A scheme for obtaining integral and fractional multiples of a given radiance, J. Opt. Soc. Am. (Letter to Editor) **53**, 1448–1449 (Dec. 1963).

Evans, J. P., Burns, G. W., A study of stability of high temperature platinum resistance thermometers, Proc. Advisory Committee on Thermometry to the Intern. Comm. on Weights and Measures, 6th Session, pp. 62–63 (Sept. 26–27, 1962).

Fano, U., Penetration of protons, alpha particles, and mesons, Ann. Rev. Nuclear Sci. **13**, 1–66 (Dec. 1963).

Fano, U., Precession equation of a spinning particle in nonuniform fields, Phys. Rev. **133**, No. 3B, B828–B830 (Feb. 10, 1964).

Fano, U., Pressure broadening as a prototype of relaxation, Phys. Rev. **131**, No. 1, 259–268 (July 1, 1963).

Fano, U., Prats, F., On the connection between the theories of collisions and of atomic spectra, Proc. Natl. Acad. Sci., India **XXXIII**, pt. IV, 553–562 (1963).

Farley, D. T., Jr., A plasma instability resulting in field-aligned irregularities in the ionosphere, J. Geophys. Res. **68**, No. 22, 6083–6097 (Nov. 15, 1963).

Farley, D. T., Jr., The effect of coulomb collisions on incoherent scattering of radio waves by a plasma, J. Geophys. Res. **69**, No. 1, 197–200 (Jan. 1, 1964).

Farley, D. T., Jr., Two-stream plasma instability as a source of irregularities in the ionosphere, Phys. Rev. Letters **10**, 279–282 (Apr. 1, 1963).

Fearn, J. E., Wall, L. A., Polymers and telomers of 4-chloroperfluoroheptadiene-1,6, SPE Trans. **3**, No. 3, 231–234 (July 1963).

Fehsenfeld, F., Cyclotron resonance in slightly ionized gases, J. Chem. Phys. **39**, No. 7, 1653–1661 (Oct. 1, 1963).

Ferguson, E. E., Infrared spectroscopy of weak charge-transfer complexes, J. Chim. Phys. **61**, 257–262 (1964).

Ferguson, E. E., Broida, H. P., Charge-transfer absorption spectra of NO in Kr and CH_3OH solutions, J. Chem. Phys. **40**, No. 12, 3715–3716 (June 15, 1964).

Fetters, L. J., Solvent participation in the anionic polymerization of styrene, Polymer Letters **2**, 425–428 (Apr. 1964).

Fey, L., Atkinson, W. R., Newman, J., Obscurities of oscillator noise, Proc. IEEE (Letter to Editor) **52**, 104–105 (Jan. 1964).

Florin, R. E., Wall, L. A., Gamma irradiation of polytetrafluoroethylene in chlorine, SPE Trans. **3**, No. 4, 290–299 (Oct. 1963).

Florman, E. R., Tary, J. J., Required signal-to-noise ratios, carrier power, and bandwidth to achieve a given performance for multichannel radio communications systems, Proc. Mountain States Navy Research and Development Clinic, Raton, N. M., Sept. 28–29, 1961, pp. A135–A140 (Raton, Communications and Electronics Foundation, 1963).

Flynn, J. H., Morrow, W. L., Effects of deuteration and temperature upon the photolysis of cellulose in a vacuum with 2537 Å light, J. Polymer Sci. **A2,** No. 1, 91–103 (Jan. 1964).

Flynn, J. H., Morrow, W. L., Photolysis of cellulose in a vacuum with 2537 Å light, J. Polymer Sci. **A2,** No. 1, 81–89 (Jan. 1964).

Forman, R. A., Nitrogen NMR chemical shifts in the azide ion, J. Chem. Phys. **39,** No. 9, 2393 (Nov. 1, 1963).

Forman, R. A., Lide, D. R., Jr., Quadrupole coupling constants from the microwave spectrum of hydrazoic acid, J. Chem. Phys. **39,** No. 4, 1133–1134 (Aug. 15, 1963).

Forziati, A. F., Kumpula, J., Barone, J. J., Tooth fluorometer, J. Am. Dental Assoc. **67,** No. 5, 663–669 (Nov. 1963).

Fouquet, B. H., NBS microscopy resolution test chart, Proc. National Microfilm Association Meeting, San Francisco, Calif., Apr. 30-May 1, 1963, pp. 67–74 (1963).

Frederikse, H. P. R., Thurber, W. R., Hosler, W. R., Electronic transport in strontium titanate, Phys. Rev. **134,** No. 2A, 442–445 (Apr. 20, 1964).

Freeze, P. D., Review of recent developments of high temperature thermocouples, Am. Soc. Mech. Engrs. Paper No. 63–WA–212 (Nov. 1963).

French, J. L., Tapered inlet structures for pipe culverts, J. Hydraulics Div. ASCE **90,** No. HY2, 256–299 (Mar. 1964).

Furukawa, G. T., Reilly, M. L., Saba, W. G., Electrical resistance of wires of low temperature-coefficient of resistance useful in calorimetry (10 to 380 °K), Rev. Sci. Instr. (Note) **35,** No. 1, 113–114 (Jan. 1964).

Gary, R., ed., English translation of book, Vapor Presure of the Chemical Elements, by A. N. Nesmeyanov, 462 pages (Elsevier Publ. Co., New York, N.Y., 1964).

Gary, R., Bates, R. G., Robinson, R. A., Thermodynamics of solutions of deuterium chloride in heavy water from 5 to 50°, J. Phys. Chem. **68,** No. 5, 1186–1190 (May 1964).

Gates, D. M., Energy, temperature and organisms, Am. Sci. Teachers **31,** No. 4, 5 pages (May 1964).

Gates, D. M., The energy environment in which we live, Am. Scientist **51,** No. 3, 327–348 (Sept. 1963).

Gates, D. M., Benedict, C. M., Convection phenomena from plants in still air, Am. J. Botany **50,** No. 5, 563–573 (July 1963).

Gates, D. M., Calfee, R. F., Hansen, D. W., Computer transmission spectra for 2.7μ, H_2O bands, Appl. Opt. **2,** No. 11, 1117–1122 (Nov. 1963).

Gates, D. M., Harrop, W. J., Infrared transmission of the atmosphere to solar radiation, Appl. Opt. **2,** No. 9, 887–898 (Sept. 1963).

Gautier, T. N., The ionosphere and radio propagation in the lower frequencies, Science **143,** No. 3611, 1197–1199 (Mar. 13, 1964).

Geller, S. B., Mantek, P. A., A 100 megapulse per second binary counter with impedance steering, IEEE Trans. Electron. Computers **EC–12,** No. 5, 568 (Oct. 1963).

George, W. D., Status of frequency and time control, Frequency **1,** No. 7, 27–29 (Nov.–Dec. 1963).

Gerstenberg, H., Response characteristics of a 4π neutron detector, Bull. Am. Phys. Soc. **9,** pt. 2, 421 (Apr. 28, 1964).

Ghaffari, A., On Rayleigh's non-linear vibration equation, Proc. Intern. Symp. Non-Linear Vibration II, 130–133 (Sept. 1961).

Giardini, A. A., Lloyd, E. C., Editors, book, High-pressure measurement (Proc. High-Pressure Measurement Symp., New York, N.Y., Nov. 1962), 409 pages (Butterworth, Inc., Washington, D.C., 1963).

Gingerick, K. A., Lee, P. K., Efimenko, J. E., Vaporization of uranium monophosphide, Nature **200,** No. 4908, 774–776 (1963).

Ginnings, D. C., Errors in "drop" calorimetry due to sample container transitions, J. Phys. Chem. (Note) **27,** 1917–1918 (1963).

Gniewek, J. J., Effects of tensile stress on the domain structure in grain-oriented 3.25% silicon steel, J. Appl. Phys. **34,** No. 12, 3618–3622 (Dec. 1963).

Goldman, A. J., Kleinman, D., Examples relating to the simplex method, Operations Res. **12,** No. 1, 159–161 (Jan.–Feb. 1964).

Golomb, D., Rosenberg, N. W., Wright, J. W., Barnes, R. A., Formation of an electron depleted region in the ionosphere by chemical releases (Proc. 4th Intern. Space Science Symp., Warsaw, June 4–10, 1963), book, Space Research, ed. P. Muller, **IV,** 389–398 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Goodwin, R. D., Diller, D. E., Hall, W. J., Roder, H. M., Weber, L. A., Younglove, B. A., Survey of current NBS work on properties of parahydrogen (Proc. 1963 Cryogenic Eng. Conf. Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), book, Advances in Cryogenic Engineering 9, Paper D–9, 234–242 (Plenum Press, Inc., New York, N.Y., 1964).

Gray, V. E., Wright, J. R., A colorimetric method for measuring polyester degradation due to weathering, J. Appl. Polymer Sci. **7**, 2161–2174 (Nov.–Dec. 1963).

Gray, V. E., Wright, J. R., Measurement of photochemical degradation in certain plastics by color reactions with phenylenediamines, J. Appl. Polymer Sci. **8**, No. 4, 1505–1519 (1964).

Green, M. S., Piccirelli, R. A., The basis of the functional assumption in the theory of the Boltzmann equation, Phys. Rev. **132**, No. 3, 1388 (Nov. 1963).

Green, M. S., Studies in scientific and engineering manpower. Part I. Patterns of utilization of scientific and engineering manpower in the United States and certain foreign countries. Part II. Trends in salaries of scientists and engineers, 1948–1962, U.S. Department of Commerce, Office of the Assistant Secretary of Commerce for Science and Technology Staff Report: 63–1 (Oct. 1963).

Greenfeld, S. H., Effect of blowing variables on the durability of coating-grade asphalts, Ind. Eng. Chem. Products Res. Devel. **3**, 158–164 (June 1964).

Greenfeld, S. H., Summary of symposium on recent research on bituminous materials, ASTM Spec. Tech. Publ. No. 347, pp. 108–111 (May 1964).

Greenspan, M., Translational dispersion in gases, Estratto da Rendiconti della Scuola Internazionale di Fisica "E. Fermi", Corso XXVII, 73–100 (1963).

Greenspan, M., Tschiegg, C E., Audiofrequency compliances of prestressed quartz, fused silica, and aluminum, J. Acoust. Soc. Am. **36**, No. 3, 450–457 (Mar. 1964).

Guildner, L. A., Gas thermometer. Encyclopaedic Dictionary of Physics, pp. 405–406 (Pergamon Press, Inc., New York, N.Y., 1961).

Gygax, S., Kropschot, R. H., Surface currents in type II superconductors, Physics Letters **9**, No. 2, 91 (Apr. 1, 1964).

Gygax, S., Olsen J. L. Kropschot, R. H., Four critical fields in superconducting indium lead alloys, Physics Letters **8**, No. 4, 228–230 (Feb. 1964).

Haber, S., A note on some quadrature formulas for the interval (∞, ∞), Math. Computation **18**, No. 86, 313–314 (1964).

Hall, J. L., Jennings, D. A., McClintock, R. M., A study of anthracene fluorescence excited by the ruby giant pulse laser, Phys. Rev. Letters **11**, No. 8, 364–366 (Oct. 15, 1963).

Haller, W., Concentration-dependent diffusion coefficient of water in glass, Phys. Chem. Glasses 4, No. 6, 217–220 (Dec. 1963).

Halpin, J. C., Mandelkern, L., Some properties of polystyrene networks formed from oriented chains, J. Polymer Sci. Pt. B, **2**, 139–142 (1964).

Hamer, W. J., The scope of electrochemistry, J. Electrochem. Soc. **110**, No. 6, 115C (June 1963).

Hamilton, E. H., Changes in relation between refractive index and Young's modulus as the result of successive heat treatment, J. Am. Ceram. Soc. **47**, No. 4, 167–170 (Apr. 1964).

Hammond, H. K., Gloss standards and glossmeter standardization, Am. Paint J. **48**, 360–364 (Apr. 1964).

Hammond, H. K., Spectroradiometry by means of modified spectrophotometers, Appl. Opt. **2**, No. 11, 1207–1208 (Nov. 1963).

Hampson, R. F., Jr., McNesby, J. R., Akimoto, H., Tanaka, I., Mechanism of the photolysis of ethane at 1470 Å, J. Chem. Phys. **40**, No. 4, 1099–1105 (Apr. 1964).

Hansen, S. F., A mechanism for the production of certain types of VLF emissions, J. Geophys. Res. **68**, No. 21, 5925–5935 (Nov. 1, 1963).

Harris, W. P., Precise determination of the area of guarded electrodes for accurate dielectric measurements on solid-disk specimens, (Proc. Conf. Electric Insulation), 1963 Annual Report. Natl. Acad. Sci-Natl. Res. Council Publ. 1141, p. 71 (1964).

Harrison, W. N., Pitfalls in thermal emission studies (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1963), NASA Spec. Publ. SP–31, Session I, Paper 1, pp. 3–10 (Dec. 1963).

Herron, J. T., Mass spectrometric study of the recombination of bromine and chlorine atoms on Pyrex, J. Phys. Chem. **67**, No. 12, 2864–2865 (Dec. 1963).

Herron, J. T., Klein, F. S., Mass spectrometric study of the isotopic exchange rate of oxygen atoms with O_2, NO and NO_2, J. Chem. Phys, **40**, No. 9, 2731 (May 1964).

Hetzer, H. B., Robinson, R. A., Bates, R. G., Thermodynamics of aqueous solutions of hydriodic acid from electromotive force measurements of hydrogen-silver iodide cells, J. Phys. Chem. **68**, No. 7, 1929–1933 (1964).

Hinchman, W. R., Buck, A. L., Fluctuations in a laser beam over 9 and 90 mile paths, Proc. IEEE **52**, No. 3, 305–306 (Mar. 1964).

Hochstrasser, U. W., Stoneley, R., The transmission of Rayleigh waves across an ocean floor with two surface layers, Geophys. J. (Jeffreys Jubilee Number) **4**, 197–201 (1961).

Hoer, C. A., Harrington, R. D., An air core primary radio frequency permeameter for reversible permeability measurements, Proc. IEEE **51**, No. 12, 1795–1796 (Dec. 1963).

Hoerman, K. C., Mancewicz, S. A., Fluorometric demonstration of tryptophan in dentin and bone protein, J. Dental Res. **43**, No. 2, 276X280 (Mar.–Apr. 1964).

Hoover, T. B., Conductance of potassium chloride in highly purified N-methylpropionamide from 20 to 40°, J. Phys. Chem. **68**, No. 4, 876–879 (Apr. 1964).

Horn, J. D., Aspects of radio meteorology, Proc. Mountain States Navy Research and Development Clinic, Raton, N. Mex. Sept. 28–29, 1961, pp. C51–C56 (Raton, Communications and Electronics Foundation, 1963).

Horowitz, E., Mandel, J., Determination of bitumen content in expansion joint fillers, Mater, Res. Std. **3**, No. 9, 723–725 (Sept. 1963).

Horowitz, E., Perros, T. P., Thermal stability of *bis* (8-hydroxy-5-quinolyl) methane coordination polymers, J. Inorg. Nucl. Chem. **26**, No. 1, 139–159 (Jan. 1964).

Houck, J. C., Hutton, U. O., Correlation of factors influencing the pressures generated in multianvil devices, book, High-Pressure Measurement, ed. A. A. Giardini and E. C. Lloyd, pp. 221–245 (Butterworth Inc., Washington, D.C., 1963).

Hubbell, J. H., Dose fields from plane sources using point source data, Nucleonics **21**, No. 8, 144–148 (Aug. 1963).

Hudson, G. E., Atkinson, W., On the redefinition of the second and the velocity of light, IEEE Trans. Instr. Meas. **IM–12**, No. 1, 44–46 (June 1963).

Hughes, E. E., Mann, W. B., The half-life of carbon–14: comments on the mass-spectrometric method, Intern. J. Appl. Radiation Isotopes **15**, No. 1, 97–100 (Jan. 1964).

Hust, J. G., Gosman, A. L., Functions for the calculation of entropy, enthalpy, and internal energy for real fluids using equations of state and specific heats (Proc. 1963 Cryogenic Eng. Conf. Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), book, Advances in Cryogenic Engineering 9, Paper D–8, 227–233 (Plenum Press, Inc., New York, N.Y., 1964).

Jackson, J. L., Coriell, S. R., On associated ions in polyelectrolytes and trapped Brownian trajectories, J. Chem. Phys. (Note) **40**, No. 5, 1460–1461 (Mar. 1, 1964).

Jackson, J. L., Klein, L. S., Continuum theory of a plasma, Phys. Fluids **7**, No. 2, 232–241 (Feb. 1964).

Jackson, J. L., Klein, L. S., Potential distribution method in equilibrium statistical mechanics, Phys. Fluids **7**, No. 2, 228–231 (Feb. 1964).

Jackson, J. W., Waxman, M., An analysis of pressure and stress distribution under rigid Bridgman-type anvils, book, High-Pressure Measurement, ed. A. A. Giardini and E. C. Lloyd, pp. 39–58 (Butterworth, Inc., Washington, D.C., 1963).

Jacox, M. E., Milligan, D. E., Low temperature infrared studies of the chemistry of free radicals, Appl. Opt. **3**, No. 7, 873–876 (July 1964).

Jacox, M. E., Milligan, D. E., Low temperature infrared study of intermediates in the photolysis of HNCO and DNCO, J. Chem. Phys. **40**, No. 9, 2457–2460 (May 1964).

James, T. C., Intensity of the forbidden $X^2\Pi_{3/2}$–$X^2\Pi_{1/2}$ satellite bands in the infrared spectrum of nitric oxide, J. Chem. Phys. **40**, No. 3, 762–771 (Feb. 1, 1964).

James, T. C., Klemperer, W., Intensity of the quadrupole fundamental of molecular hydrogen rotation-vibration interaction correction, J. Chem. Phys. **40**, No. 3, 914–915 Feb. 1, 1964).

James, T. C., Plyler, E. K., Linewidths in the 2–O band of carbon monoxide broadened by nitrogen and hydrogen, J. Chem. Phys. **40**, No. 1, 221–223 (Jan. 1, 1964).

James, T. C., Thibault, R. J., Pressure broadening of DCl by HCl and HCl by DCl. A comparison of experimental results with Anderson's theory, J. Chem. Phys. **40**, No. 2, 534–540 (Jan. 15, 1964).

Janes, H. B., Correlation of the phase of microwave signals on the same line-of-sight path at different frequencies, IEEE Trans. Ant. Prop. **AP-11**, No. 6, 716–717 (Nov. 1963).

Jeffries, J. T., Line transfer problems, J. Quant. Spectry. Radiative Transfer **3**, No. 2, 217–220 (Apr.–June 1963).

Jenkins, W. D., Willard, W. A., Some factors affecting the creep behavior of an age-hardenable alloy, Am. Soc. Metals Trans. Quart. **56**, No. 3, 427–441 (Sept. 1963).

Jensen, M. W., Weights and measures and aerosols, Proc. 50th Annual Meeting Chemical Specialties Manufacturers Association, pp. 33–35 (Dec. 1963); Scale J. **50**, No. 6, 2 (Mar. 1964).

Jespersen, J. L., Kamas, G., Satellite scintillation observations at Boulder, Colo., J. Atmospheric Terrest. Phys. **26**, 457–473 (1964).

Johler, J. R., The propagation time of a radio pulse, IEEE Trans. Ant. Prop. **AP–11**, No. 6, 661–668 (Nov. 1963).

Johler, J. R., Berry, L. A., On the propagation of long wave-length terrestrial radio waves—two theoretical techniques, AGARDograph 74, Propagation of Radio Waves Below 300 Kilocycles, pp. 101–129 (Pergamon Press, Inc., New York, N.Y., 1963).

Johnson, V. J., Introduction, Am. Soc. Refrigerating and Air Conditioning Engineers Symp., The Role Cryogenics is Playing in Expanding Mechanical Engineering at the semi-annual meeting of the Am. Soc. of Heating, Refrigerating and Air Conditioning Engineers, New York, N.Y., Feb. 11–14, 1963, pp. iii–iv (1964).

Jones, E., Use of high-strength ceramics in vibration transducers, J. Acoust. Soc. Am. **36**, No. 6, 1215–1216 (June 1964).

Jones, F. E., Castle, A. B., Sr., Magnetically retained evaporation mask, Rev. Sci. Instr. **34**, No. 9, 1055 (Sept. 1963).

Kanagy, J. R., Macro-pores in leather as determined with a mercury porosimeter, J. Am. Leather Chemists' Assoc. **LVIII**, No. 9, 524–550 (Sept. 1963).

Kearsley, E. A., Bernstein, B., Zapas, L. J., A study of stress relaxation with finite strain, Trans. Soc. Rheology **VII**, 391–410 (1963).

Keegan, H. J., Schleter, J. C., Belknap, M. A., Recalibration of the NBS glass standards of spectral transmittance, J. Opt. Soc. Am. **54**, No. 1, 69–74 (Jan. 1964).

Kelly, K. L., Lines of constant correlated color temperature based on MacAdam's (u,v) uniform chromaticity transformation of the CIE diagram, J. Opt. Soc. Am. **53**, No. 8, 999–1002 (Aug. 1963).

Kerns, D. M., Generalized variational principles for electromagnetic vibrations; application to the theory of waveguide junctions, Proc. Symp. Electromagnetic Theory and Antennas, Copenhagen, June 25–30, 1962, pp. 253–259 (Pergamon Press, Inc., London, England, 1963).

Kerper, M. J., Scuderi, T. G., Mechanical properties of glass at elevated temperatures, Bull. Am. Ceram. Soc. **42**, No. 12, 735–740 (Dec. 1963).

Kidnay, A. J., Hiza, M. J., The adsorption of methane and nitrogen on silica gel, synthetic zeolite, and charcoal, J. Phys. Chem. **67**, 1725–1727 (Aug. 1963).

Kirby, R. S., Long-term characteristics for air-ground propagation in band nine, Program and Digest 1963 IEEE Prof. Group Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 43–47 (1963).

Klein, M., Approximations to the pair correlation function for a hard sphere fluid, Phys. Fluids **7**, No. 3, 391–401 (Mar. 1964).

Klein, M., Numerical solutions of the convolution-hypernetted chain integral equation for the pair correlation function of a fluid. II. The hard sphere potential, J. Chem. Phys. **39**, No. 6, 1388–1397 (Sept. 15, 1963).

Klein, M., Green, M. S., Numerical solutions of the convolution-hypernetted chain integral equation for the pair correlation function of a fluid. I. The Lennard-Jones (12.6) potential, J. Chem. Phys. **39**, No .6, 1367–1387 (Sept. 15, 1963).

Klein, R., Scheer, M. D., Hydrogen atom addition to solid four-carbon olefins, J. Phys. Chem. **67**, 1874–1877 (Sept. 1963).

Klein, R., Scheer, M. D., Kelley, R., Disproportionation-combination reactions of alkyl radicals and hydrogen atoms at low temperatures, J. Phys. Chem. **68**, No. 3, 598–605 (Mar. 1964).

Klemperer, W. K., Ochs, G. R., Bowles, K. L., Radar echoes from Venus at 50 Mc/s, Astron, J **69**, No. 1, 22–28 (Feb. 1964).

Kline, G. M., Developments in polymer evaluation procedures (Atti del XV Congresso Internazionale delle materie plastiche, Turin, Italy, Sept. 26–28, 1963), Mod. Plastics **41**, No. 5, 182 (Jan. 1964).

Kline, G. M., NBS activities for the American Rubber Industry, L'Industria della Gomma **VII**, No. 6, 29–33 (June 1963).

Kline, G. M., Plastics, Americana Annual, p. 532 (Americanan Corp., Chicago, Ill., 1964).

Knecht, R. W., Radio, the ionosphere, and IQSY, Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, **XIII**, 181–194 (1964).

Knecht, R. W., Rishbeth, H., VanZandt, T. E., On the constitution of the topside ionosphere (Proc. NATO Advanced Study Inst., Skeikampen, Norway, Apr. 17–26, 1963), book, Electron Density Distribution in the Ionosphere and Exosphere, pp. 348–350 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Knecht, R. W., Russell, S., Jackson, J. E., First results in NASA topside sounder satellite, Book, Advances in the Astronautical Sciences 11, 61–85 (Western Periodicals Co., Calif., 1963).

Kneisly, J. A., II, Local curvature of wavefronts in an optical system, J. Opt. Soc. Am. **54**, No. 2, 229–235 (Feb. 1964).

Koch, H. W., Electromagnetic cross sections for electron and nuclear research, Nucl. Instr. Methods **28**, 199–204 (1964).

Koch, H. W., Pruitt, J. S., Determination of differential X-ray photon flux and total beam energy, book, Nuclear Physics, ed. L. C. Yugan and C. Wu, 5, Ch. 2.8.2, 508–533 (1963).

Kostkowski, H. J., Burnes, G. W., Thermocouple and radiation thermometry above 900 °K (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1963), NASA Spec. Publ. SP–31, Session I, Paper 3, pp. 13–30 (Dec. 1963).

Krauss, M., Weiss, A. W., Pair correlations in closed-shell systems, J. Chem. Phys. **40,** No. 1, 80–85 (Jan. 1964).

Kropschot, R. H., Some low temperature properties of materials, Proc. Mountain States Navy Research and Development Clinic, Raton, N. Mex., Sept. 28–29, 1961, pp. D5–D6 (Raton, Communications and Electronics Foundation, 1963).

Kruger, J., Yolken, H. T., Room temperature oxidation of iron at low pressures, Corrosion **20,** No. 1, 29t–33t (Jan. 1964).

Krupenie, P. H., Interaction energies and transport coefficients of Li+H and O+H gas mixtures at high temperatures, J. Chem. Phys. **39,** No. 10, 2399–2408 (Nov. 15, 1963).

Ku, H. H., A note on contingency table involving zero frequencies and the 2I test, Technometrics **5,** No. 3, 398–400 (Aug. 1963).

Kusuda, T., Achenbach, P. R., Numerical analysis of the thermal environment of occupied underground spaces with finite cover using a digital computer, ASHRAE Trans. and J. **6,** No. 6. 99–105 (June 1964).

Kuyatt, C. E., Mielczarek, S. R., Simpson, J. A., Energy losses and elastic resonances in electron scattering from H_2, Phys. Rev. Letters **12,** 293 (1964).

Kuyatt, C. E., Simpson, J. A., Inelastic electron scattering from rare gases, determination of oscillator strengths in the continuum, (Proc. 3d Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963), Book, Atomic Collision Processes, ed. M.R.C. McDowell, pp. 191–200 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Kuyatt, C. E., Simpson, J. A., Structure beyond the ionization limit in inelastic electron scattering in the rare gases, Proc. 6th Intern. Symp. Ionization Phenomena in Gases IA11, 33–35 (Paris, 1963).

Labrie, R. J., Cation-exchange between molten salts and a special porcelain of high sodium content, J. Electrochem. Soc. **111,** No. 4, 473–476 (Apr. 1964).

Labrie, R. J., Lamb, V. A., Transference numbers in pure molten sodium nitrate, J. Electrochem. Soc. **110,** No. 7, 810–814 (July 1963).

Lafferty, W. J., Maki, A. G., Plyler, E. K., High-resolution infrared determination of the structure of carbon suboxide, J. Chem. Phys. **40,** No. 1, 224–229 (Jan. 1, 1964).

Lamb, V. A., Thomas, C. T., Iron, Mod. Electroplating, pp. 228–241 (1963).

Larsen, D. M., Binary mixtures of dilute bose gases with repulsive interactions at low temperature, Ann. Phys. **24,** 89–101 (1963).

Larsen, D. M., Polarons in an electric field, Phys. Rev. **133,** No. 3A, A860–A866 (Feb. 3, 1964).

Larson, W., Analysis of rotation errors of a waveguide rotary-vane attenuator, IEEE Trans. Instr. Meas. **IM–12,** No. 2, 50–55 (Sept. 1963).

Larson, W., Inline waveguide attenuator, IEEE Trans. Microwave Theory Tech. (Corres. Sec.) **MTT–12,** No. 3, 367–368 (May 1964).

Lauritzen, J., The effective area of a guarded electrode (Proc. Conf. Electric Insulation), 1963 Annual Report, Natl. Acad. Sci.-Natl. Res. Council Publ. 1141, pp. 67–70 (1963).

Lavilla, R. E., Mendlowitz, H., Optical constants of thin films from the characteristic electron energy losses, J. Phys. **25,** Nos. 1 & 2, 114–118 (Jan.–Feb. 1964).

Lavilla, R. E., Bauer, S. H., The structure of gaseous copper (II) nitrate as determined by electron diffraction, J. Am. Chem. Soc. **85,** No. 20, 3597–3600 (Nov. 1963).

Lawrence, R. S., Little, C. G., Chivers, H. J. A., A survey of ionospheric effects upon earth-space radio propagation, Proc. IEEE **52,** No. 1, 4–27 (1964).

Leaderman, H., Some aspects of the mechanical properties of high polymers (Proc. Conf. Mechanical Behavior of Wood, Univ. Calif., Berkeley, Calif., Sept. 1962), Book, Mechanical Behavior of Wood, pp. 43–83 (1964).

Leaderman, H., McCracken, F., Large longitudinal retarded elastic deformation of rubberlike network polymers. II. Application of a general formulation of nonlinear response, Trans. Soc. Rheology **VII,** 111–123 (1963).

Lee, R. D., Some results and problems in calibrating the NBS photoelectric pyrometer of 1961, Proc. Advisory Committee on Thermometry to the Intern. Comm. on Weights and Measures, 6th Session, pp. 79–90 (Sept. 26–27, 1962).

Lehner, J., Newman, M., Weierstrass points of $\Gamma_0(n)$, Ann. Math. **79,** No. 1, 360–368 (1964).

Leiss, J. E., Beam loading and beam blowup in electron linacs, Proc. Conf. Proton Linear Accelerators, Yale Univ., New Haven, Conn., pp. 74–95 (Oct. 1963).

Leiss, J. E., Prebunching in electron linacs, Proc. Conf. Proton Linear Accelerators, Yale Univ., New Haven, Conn., pp. 267–273 (Oct. 1963).

Leiss, J. E., Broberg, J., Schrack, R., Wyckoff, J. M., On-line data handling system for the National Bureau of Standards LINAC, IEEE Trans. Nuclear Sci. **NS–11,** No. 3, 331–337 (June 1964).

Lerfald, G. M., Little, C. G., Parthasarathy, R., D-region electron density profiles during auroras, J. Geophys. Res. **69**, 2857–2860 (June 1964).

Leslie, R. T., Kuehner, E. C., Distillation analysis, Anal. Chem. **36**, No. 5, 56R–70R (Apr. 1964).

Lessing, P., Catanzaro, E. J., Sr^{87}/Sr^{86} ratios in Hawaiian lavas, J. Geophys. Res. **69**, No. 8, 1599–1601 (Apr. 15, 1964).

Levin, E. M., Refractivities of the rare earth oxides (Proc. Third Rare Earth Research Conf., Apr. 2–24, 1963), book, Rare Earth Research, Chapter on Magnetic and Optical Studies, pp. 339–350 (Gordon & Breach Science Publ., Inc., New York, N.Y., May 1964).

Levin, E. M., Robbins, C. R., McMurdie, H. F., Phase diagrams for ceramists, book, Am. Ceramic Society Inc., Columbus, Ohio, 1964.

Levinson, C. A., Lipkin, H. J., Meshkov, S., A unitary symmetry selection rule and its application to new resonances, Il Nuovo Cimento **32**, Ser. X, 1376–1379 (1964).

Levinson, C. A., Lipkin, H. V., Meshkov, S., Experimental predictions from unitary symmetry (SU_3), (Proc. 1963 Intern. Conf. Nucleon Structure, Stanford Univ., Calif., June 24–27, 1963), book, Nucleon Structure, p. 309 (University Press, Stanford, Calif., Aug. 11, 1963).

Levinson, C. A., Lipkin, H. J., Meshkov, S., Unitary symmetry in photoproduction and other electromagnetic interactions, Phys. Letters **7**, No. 1, 81–84 (Oct. 15, 1963).

Lide, D. R., Jr., Cahill, P., Gold, L. P., Microwave spectrum of lithium chloride, J. Chem. Phys. **40**, No. 1, 156–159 (Jan. 1964).

Lide, D. R., Jr., Jen, M., Microwave studies of butadiene derivatives. II. Isoprene, J. Chem. Phys. **40**, No. 1, 252–253 (Jan. 1964).

Lincoln, J. V., Solar activity, IQSY Instruction Manual No. 2. Report of Sudden Ionospheric Disturbances, Suppl., pp. 1–11 (IQSY Secretariat, London, England, 1963).

Lincoln, J. V., The listing of sudden ionospheric disturbances, Planetary Space Sci. **12**, No. 5, 419–434 (May 1964).

Lipkin, H. J., Levinson, C. A., Meshkov, S., On the production of the Z^- (Ω^-) baryon, Physics Letters **7**, No. 2, 159–161 (Nov. 1, 1963).

Lisle, R. V., Zapf, T. L., Comparison calibration of inductive voltage dividers, ISA 1963 Proc. Paper No. 7.1.63 (1963).

Little, C. G., Lerfald, G. M., Parthasarathy, R., The use of dual-polarized broad beam antennas to determine the extraterrestrial intensity of the cosmic radio noise at high frequencies, Program and Digest 1963 IEEE Prof. Group Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 9–15 (1963).

Little, W. E., Wakefield, J. P., A coaxial adjustable sliding termination, IEEE Trans. Microwave Theory Tech. **MTT–12**, No. 2, 247–248 (Mar. 1964).

Logan, H. L., McBee, M. J., Romanoff, M., Stress-corrosion cracking of type 304 stainless steel at 455 to 615 °F, Mater. Res. Std. **3**, No. 8, 635–639 (Aug. 1963).

McCamy, C. S., Instant color correction, Mod. Photo. **28**, No. 1, 66–67 (Jan. 1964).

McCarty, R. D., Stewart, R. B., Preliminary thermodynamic properties of neon (Proc. 1963 Cryogenic Eng. Conf. Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering 9, Paper B-4, 161–167 (Plenum Press, Inc., New York, N.Y., 1964).

McDonald, E. J., Report on sugars and sugar products, J. Assoc. Official Agri. Chem. **46**, 35 (1963).

McKinley, J. D., Mass spectrometric investigation of the high temperature reaction between nickel and chlorine, J. Chem. Phys. **40**, No. 1, 120–125 (Jan. 1, 1964).

McKinley, J. D., Mass spectrometric investigation of the nickel-bromine surface reaction, J. Chem. Phys. **40**, No. 2, 576–581 (Jan. 1964).

McLaughlin, W. L., Photographic dosimetry, megaroentgen range, Encyclopaedia of X-rays and Gamma Rays, ed. G. L. Clark, pp. 307–309 (Rheinhold Publ. Corp., New York, N.Y., 1963).

McNish, A. G., Standards and contact lenses, CONTACTO **7**, No. 9, 4–5 (Nov.–Dec. 1963).

McPherson, A. T., Electrical properties of elastomers and related polymers, Rubber Chem. Technol. **36**, No. 5, 1230–1302 (Dec. 1963).

McPherson, A. T., Standardization from the national viewpoint, SES Proc. 12th Annual Meeting, Sept. 1963, Washington, D.C., pp. 68–72 (1963).

McPherson, A. T., The second industrial revolution (Spanish translation of), Linea Recta **132**, No. 669, 348–354 (1963).

McPherson, A. T., Best, A. S., Standardization of dimensions of packages for self-service selling, THE PACKETT, Packaging Professional **2**, No. 3, 4–5 (Packaging Inst., 1964).

Madden, R. P., Codling, K., Autoionization in helium using a synchrotron light source, Proc. VIth Intern. Conf. Ionization Phenomena in Gases, Paris, France, 1963, 1, 139–143 (1963).

Madden, R. P., Codling, K., Recently discovered autoionizing states of krypton and xenon in the λ 380–600A, J. Opt. Soc. Am. **54**, No. 2, 268–269 (Feb. 1964).

Madorsky, S. L., Thermal Degradation of Organic Polymers, Book, 315 pages (Interscience Publ., Inc., New York, N.Y., 1964).

Maeda, H., Matsushita, S., Shirgaokar, M., Yashuhara, M., On the geomagnetic effect of the Starfish high-altitude nuclear explosion, J. Geophys. Res. **69**, No. 5, 917–945 (Mar. 1, 1964).

Maienthal, E. J., Determination of rhodium in rhodium-uranium alloys by precipitation with hydrogen sulfide, Anal. Chem. **35**, No. 7, 1094–1095 (July 1963).

Maienthal, E. J., Taylor, J. K., Separation and determination of zirconium in zirconia yttria mixtures by precipitation with cupferron, Anal. Chem. **36**, No. 7, 1286–1287 (June 1964).

Maki, A. G., Blaine, L. R., Infrared spectra of HCN from 2000 to 3600 cm^{-1}, J. Mol. Spectry. **12**, No. 1, 45–68 (Jan. 1, 1964).

Malitson, I. H., A redetermination of some optical properties of calcium fluoride, Appl. Opt. **2**, No. 11, 1103–1107 (Nov. 1963).

Malitson, I. H., Refractive properties of barium fluoride, J. Opt. Soc. Am. **54**, No. 5, 628–632 (May 1964).

Malitson, I. H., Cleek, G. W., Stavroudis, O. N., Sutton, L. E., Infrared dispersion of some oxide glasses, Appl. Opt. **2**, No. 7, 741–747 (July 1963).

Mandel, J., Estimation of weighting factors in linear regression and analysis of variance, Technometrics **6**, No. 1, 1–25 (Feb. 1964).

Mandelkern, L., Canty, G., Diorio, A. F., The melting (contraction) and recrystallization of fibrous proteins in nonaqueous media, J. Phys. Chem. **67**, No. 12, 2882–2884 (Dec. 1963).

Mann, D. E., White, D., Seshadri, K. S., Dever, D. F., Linevsky, M. J., The infrared spectra, structures and thermodynamics of gaseous LiO, Li_2O, and Li_2O_2, J. Chem. Phys. **39**, No. 10, 2463–2473 (Nov. 1963).

Mann, W. B., Medlock, R. W., Yura, O., A recalibration of the National Bureau of Standards tritiated water standard, Intern. J. Appl. Radiation Isotopes **15**, No. 6, 351–361 (June 1964).

Marcus, M., Minc, H., The Pythagorean theorem in certain symmetry classes of tensors, Trans. Am. Math. Soc. **104**, No. 3, 510–515 (Sept. 1962).

Marshak, H., Wagner, R., Miller, P. P., Tamura, T., The interaction of 350 keV polarized neutrons with oriented Ho^{165} nuclei, Phys. Letters **10**, No. 3, 316 (June 15, 1964).

Martin, G. M., Mandelkern, L., The effect of hydrostatic pressure on the crystallization kinetics of natural rubber, J. Appl. Phys. **34**, No. 8, 2312–2317 (Aug. 1963).

Martin, W. C., Low energy levels of neutral cerium (Ce I), J. Opt. Soc. Am. **53**, No. 9, 1047–1050 (Sept. 1963).

Marton, L., Marton, C., Characteristics energy losses of electrons in solids, book, Actions Chimiques et Biologiques des Radiations, Ch. IV, pp. 260–281 (Mason et C^{ie} Editeurs, Paris, France, 1964).

Mason, H. L., Analog simulation of zone melting, Instr. Control Systems **37**, No. 1, 121–123 (Jan. 1964).

Matsushita, S., Ionospheric storms, Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, **XIII**, 169–180 (1964).

Maximon, L. C., Isabelle, D. B., Radiative tail in elastic electron scattering, Phys. Rev. Letters **133**, No. 5B, 1344–1350 (Mar. 9, 1964).

Mazur, J., Statistical thermodynamics of the lattice model of a polymer molecule, J. Chem. Phys. **40**, No. 4, 1001–1007 (Feb. 1964).

Mazur, J., Rubin, R. J., Coefficient of thermal expansion and Young's modulus for a one-dimensional model of a solid, Am. J. Phys. **34**, No. 11, 835–836 (Nov. 1963).

Meggers, W. F., Review of reviews of atomic spectroscopy, Appl. Opt. **2**, No. 7, 657–663 (July 1963).

Megill, L. R., Carleton, N. P., Excitation by local electric fields in the aurora and airglow, J. Geophys. Res. **69**, No. 1, 101–122 (Jan. 1, 1964).

Mendlowitz, H., Transition array for d^3d^2p: vanadium, Astrophys. J. **138**, No. 4, 1277–1296 (Nov. 15, 1963).

Merrill, R. G., Lawrence, R. S., Roper, N. J., Synoptic variations and vertical profiles of large-scale ionospheric irregularities, J. Geophys. Res. **68**, No. 19, 5453–5459 (Oct. 1, 1963).

Meshkov, S., Comparison of experimental reaction cross sections with various relations obtained from SU_3, Proc. Conf. Symmetry Principles at High Energy, Coral Gables, Fla., Jan. 30, 1964, pp. 104–126 (1964).

Meshkov, S., Snow, G. A., Yodh, G. B., Comparison of a new SU_3 prediction with experiment, Phys. Rev. Letters **12**, No. 3, 87–92 (Jan. 20, 1964).

Meyer-Arendt, J. R., Frostbite: signs, prevention, and treatment, Trail and Timberline, p. 3 (Jan. 1964).
Meyer-Arendt, J. R., Herrick, R. B., Emmanuel, C. B., Determination of optical thickness gradients from a far distance, J. Opt. Soc. Am. **53**, 1344 (1963).
Meyerson, M. R., Pennington, W. A., Gage blocks of superior stability. II. Fully hardened steels. Am. Soc. Metals Trans. Quart. **57**, No. 1, 3–25 (Mar. 1964).
Meyerson, M. R., Sola, M. S., Gage blocks of superior stability. III. The attainment of ultrastability, Am. Soc. Metals Trans. Quart. **57**, No. 1, 164–185 (Mar. 1964).
Michaelis, R. E., Report of Committee E–2 on Emission Spectroscopy, Am. Soc. Testing Mater. Proc. **63**, 456 (1963).
Michaelis, R. E., Report on standard samples, reference samples, and high-purity materials for spectrochemical analysis, ASTM Spec. Tech. Publ. **58–E** (1963).
Michaelis, R. E., Suggested practices for establishing sampling and sample preparation techniques in spectrochemical analysis, book, Methods for Emission Spectrochemical Analysis, 4th ed., pp. 256–259 (American Society for Testing Materials, Phila., Pa., Feb. 1964).
Michaelis, R. E., Summary of Sessions I and II of the Symposium on X-ray and Electron Probe Analysis, ASTM Spec. Tech. Publ. 349 (1963).
Mielenz, K. D., Note on "Interferometric measurement of vibration amplitudes," Appl. Opt. **3**, 542 (Apr. 1964).
Mies, F. H., Effects of anharmonicity on vibrational energy transfer, J. Chem. Phys. **40**, No. 2, 523–531 (Jan. 1964).
Milligan, D. E., Jacox, M. E., Infrared spectra of NF, NCl, and NBr, J. Chem. Phys. **40**, No. 9, 2461–2466 (May 1964).
Minnhagen, L., Correlation between observed wavelength shifts produced in electrodeless discharge tubes and predicted Stark-effect shifts in the spectrum of neutral germanium (Ge I), J. Opt. Soc. Am. **54**, No. 3, 320–322 (Mar. 1964).
Moore, C. E., International Symposium on the Solar Spectrum, Utrecht, Aug. 26–31, 1963, Appl. Opt. 3, No. 1, 12 (Jan. 1964).
Moore, C. E., Minutes of the Meeting at the Ohio State University, Columbus, Ohio, of the Triple Commission for Spectroscopy, June 12, 1963, J. Opt. Soc. Am. **54**, No. 3, 425–432 (Mar. 1964).
Moore, C. E., The atomic spectra of the rare earths: their presence in the sun, Appl. Opt. **2**, No. 7, 665–674 (July 1963).
Moore, C. E., The ultraviolet realm of spectroscopy, J. Wash. Acad. Sci. **54**, 58–62 (Mar. 1964).
Moore, C. E., Branscomb, L. M., Annual "observatory report" on research at the National Bureau of Standards, Astron. J. **68**, No. 9, 657–659 (Nov. 1963).
Moore, D. G., Investigation of shallow reference cavities for high-temperature emittance measurements (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1963), NASA Spec. Publ. SP–31, Session V, Paper 52, p. 515 (Dec. 1963).
Moore, G. A., Direct quantitative analysis of photomicrographs by a digital computer, Phot. Sci. Eng. **8**, No. 3, 152–161 (May–June 1964).
Mordfin, L., Hasley, N., Programmed maneuver-spectrum fatigue tests of aircraft beam specimens, ASTM Spec. Tech. Publ. No. 338, pp. 251–272 (Sept. 1963).
Morgan, A. H., Frequency and time broadcast services of the National Bureau of Standards, Proc. ISA 17th Annual Automation Conf. and Exhibit, New York, N.Y., Oct. 15–18, 1962, Pt. I, Paper 1.1.62, 9 pages (1962).
Motz, J. W., Placious, R. C., Large-angle inelastic scattering of 500-keV electrons, Phys. Rev. **132**, No. 3, 1120–1122 (Nov. 1963).
Motz, J. W., Placious, R. C., Dick, C. E., Coulomb scattering without atomic excitation for 50-, 100-, 200-, and 400-keV electrons, Phys. Rev. **132**, No. 6, 2258–2561 (Dec. 15, 1963).
Murphey, W. M., Chin, J., Intercomparisons of the standard thermal-neutron flux density of the National Bureau of Standards (Proc. Symp. Neutron Detection, Dosimetry and Standardization, International Atomic Energy Agency, Atomic Energy Research Establishment, Harwell, England, Dec. 10–14, 1962), book, Neutron Dosimetry II, 513–521 (International Atomic Energy Agency, Vienna, 1963).
Nakagawa, Y., Earnshaw, K. B., Experiments on self-ionizing shock waves in a magnetic field, book, Compt. Rend. VI[e] Conf. Intern. sur les Phenomenes D'Ionisation dans les Gaz, ed. P. Hubert and E. Cremieu-Alcan, **IV**, 303–309 (S.E.R.M.A., Publ. Co., Paris, France, 1963).
Nason, M. E., Radio propagation quality in the North Atlantic Area 1953–1960, AGARDograph 59, The Effect of Disturbances of Solar Origin on Communications, ed. G. J. Gassman, pp. 287–291 (Pergamon Press, Inc., London, England, 1963).
Nesenbergs, M., Binary error probability due to an adaptable fading model, IEEE Trans. Commun. Syst. **CS–12**, No. 1, 64–73 (Mar. 1964).

Madden, R. P., Codling, K., Recently discovered autoionizing states of krypton and xenon in the λ 380–600A, J. Opt. Soc. Am. **54**, No. 2, 268–269 (Feb. 1964).

Madorsky, S. L., Thermal Degradation of Organic Polymers, Book, 315 pages (Interscience Publ., Inc., New York, N.Y., 1964).

Maeda, H., Matsushita, S., Shirgaokar, M., Yashuhara, M., On the geomagnetic effect of the Starfish high-altitude nuclear explosion, J. Geophys. Res. **69**, No. 5, 917–945 (Mar. 1, 1964).

Maienthal, E. J., Determination of rhodium in rhodium-uranium alloys by precipitation with hydrogen sulfide, Anal. Chem. **35**, No. 7, 1094–1095 (July 1963).

Maienthal, E. J., Taylor, J. K., Separation and determination of zirconium in zirconia yttria mixtures by precipitation with cupferron, Anal. Chem. **36**, No. 7, 1286–1287 (June 1964).

Maki, A. G., Blaine, L. R., Infrared spectra of HCN from 2000 to 3600 cm^{-1}, J. Mol. Spectry. **12**, No. 1, 45–68 (Jan. 1, 1964).

Malitson, I. H., A redetermination of some optical properties of calcium fluoride, Appl. Opt. **2**, No. 11, 1103–1107 (Nov. 1963).

Malitson, I. H., Refractive properties of barium fluoride, J. Opt. Soc. Am. **54**, No. 5, 628–632 (May 1964).

Malitson, I. H., Cleek, G. W., Stavroudis, O. N., Sutton, L. E., Infrared dispersion of some oxide glasses, Appl. Opt. **2**, No. 7, 741–747 (July 1963).

Mandel, J., Estimation of weighting factors in linear regression and analysis of variance, Technometrics **6**, No. 1, 1–25 (Feb. 1964).

Mandelkern, L., Canty, G., Diorio, A. F., The melting (contraction) and recrystallization of fibrous proteins in nonaqueous media, J. Phys. Chem. **67**, No. 12, 2882–2884 (Dec. 1963).

Mann, D. E., White, D., Seshadri, K. S., Dever, D. F., Linevsky, M. J., The infrared spectra, structures and thermodynamics of gaseous LiO, Li_2O, and Li_2O_2, J. Chem. Phys. **39**, No. 10, 2463–2473 (Nov. 1963).

Mann, W. B., Medlock, R. W., Yura, O., A recalibration of the National Bureau of Standards tritiated water standard, Intern. J. Appl. Radiation Isotopes **15**, No. 6, 351–361 (June 1964).

Marcus, M., Minc, H., The Pythagorean theorem in certain symmetry classes of tensors, Trans. Am. Math. Soc. **104**, No. 3, 510–515 (Sept. 1962).

Marshak, H., Wagner, R., Miller, P. P., Tamura, T., The interaction of 350 keV polarized neutrons with oriented Ho^{165} nuclei, Phys. Letters **10**, No. 3, 316 (June 15, 1964).

Martin, G. M., Mandelkern, L., The effect of hydrostatic pressure on the crystallization kinetics of natural rubber, J. Appl. Phys. **34**, No. 8, 2312–2317 (Aug. 1963).

Martin, W. C., Low energy levels of neutral cerium (Ce I), J. Opt. Soc. Am. **53**, No. 9, 1047–1050 (Sept. 1963).

Marton, L., Marton, C., Characteristics energy losses of electrons in solids, book, Actions Chimiques et Biologiques des Radiations, Ch. IV, pp. 260–281 (Mason et C^{ie} Editeurs, Paris, France, 1964).

Mason, H. L., Analog simulation of zone melting, Instr. Control Systems **37**, No. 1, 121–123 (Jan. 1964).

Matsushita, S., Ionospheric storms, Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, **XIII**, 169–180 (1964).

Maximon, L. C., Isabelle, D. B., Radiative tail in elastic electron scattering, Phys. Rev. Letters **133**, No. 5B, 1344–1350 (Mar. 9, 1964).

Mazur, J., Statistical thermodynamics of the lattice model of a polymer molecule, J. Chem. Phys. **40**, No. 4, 1001–1007 (Feb. 1964).

Mazur, J., Rubin, R. J., Coefficient of thermal expansion and Young's modulus for a one-dimensional model of a solid, Am. J. Phys. **34**, No. 11, 835–836 (Nov. 1963).

Meggers, W. F., Review of reviews of atomic spectroscopy, Appl. Opt. **2**, No. 7, 657–663 (July 1963).

Megill, L. R., Carleton, N. P., Excitation by local electric fields in the aurora and airglow, J. Geophys. Res. **69**, No. 1, 101–122 (Jan. 1, 1964).

Mendlowitz, H., Transition array for d^3d^2p: vanadium, Astrophys. J. **138**, No. 4, 1277–1296 (Nov. 15, 1963).

Merrill, R. G., Lawrence, R. S., Roper, N. J., Synoptic variations and vertical profiles of large-scale ionospheric irregularities, J. Geophys. Res. **68**, No. 19, 5453–5459 (Oct. 1, 1963).

Meshkov, S., Comparison of experimental reaction cross sections with various relations obtained from SU_3, Proc. Conf. Symmetry Principles at High Energy, Coral Gables, Fla., Jan. 30, 1964, pp. 104–126 (1964).

Meshkov, S., Snow, G. A., Yodh, G. B., Comparison of a new SU_3 prediction with experiment, Phys. Rev. Letters **12**, No. 3, 87–92 (Jan. 20, 1964).

Meyer-Arendt, J. R., Frostbite: signs, prevention, and treatment, Trail and Timberline, p. 3 (Jan. 1964).
Meyer-Arendt, J. R., Herrick, R. B., Emmanuel, C. B., Determination of optical thickness gradients from a far distance, J. Opt. Soc. Am. **53**, 1344 (1963).
Meyerson, M. R., Pennington, W. A., Gage blocks of superior stability. II. Fully hardened steels. Am. Soc. Metals Trans. Quart. **57**, No. 1, 3–25 (Mar. 1964).
Meyerson, M. R., Sola, M. S., Gage blocks of superior stability. III. The attainment of ultrastability, Am. Soc. Metals Trans. Quart. **57**, No. 1, 164–185 (Mar. 1964).
Michaelis, R. E., Report of Committee E–2 on Emission Spectroscopy, Am. Soc. Testing Mater. Proc. **63**, 456 (1963).
Michaelis, R. E., Report on standard samples, reference samples, and high-purity materials for spectrochemical analysis, ASTM Spec. Tech. Publ. **58–E** (1963).
Michaelis, R. E., Suggested practices for establishing sampling and sample preparation techniques in spectrochemical analysis, book, Methods for Emission Spectrochemical Analysis, 4th ed., pp. 256–259 (American Society for Testing Materials, Phila., Pa., Feb. 1964).
Michaelis, R. E., Summary of Sessions I and II of the Symposium on X-ray and Electron Probe Analysis, ASTM Spec. Tech. Publ. 349 (1963).
Mielenz, K. D., Note on "Interferometric measurement of vibration amplitudes," Appl. Opt. **3**, 542 (Apr. 1964).
Mies, F. H., Effects of anharmonicity on vibrational energy transfer, J. Chem. Phys. **40**, No. 2, 523–531 (Jan. 1964).
Milligan, D. E., Jacox, M. E., Infrared spectra of NF, NCl, and NBr, J. Chem. Phys. **40**, No. 9, 2461–2466 (May 1964).
Minnhagen, L., Correlation between observed wavelength shifts produced in electrodeless discharge tubes and predicted Stark-effect shifts in the spectrum of neutral germanium (Ge I), J. Opt. Soc. Am. **54**, No. 3, 320–322 (Mar. 1964).
Moore, C. E., International Symposium on the Solar Spectrum, Utrecht, Aug. 26–31, 1963, Appl. Opt. 3, No. 1, 12 (Jan. 1964).
Moore, C. E., Minutes of the Meeting at the Ohio State University, Columbus, Ohio, of the Triple Commission for Spectroscopy, June 12, 1963, J. Opt. Soc. Am. **54**, No. 3, 425–432 (Mar. 1964).
Moore, C. E., The atomic spectra of the rare earths: their presence in the sun, Appl. Opt. **2**, No. 7, 665–674 (July 1963).
Moore, C. E., The ultraviolet realm of spectroscopy, J. Wash. Acad. Sci. **54**, 58–62 (Mar. 1964).
Moore, C. E., Branscomb, L. M., Annual "observatory report" on research at the National Bureau of Standards, Astron. J. **68**, No. 9, 657–659 (Nov. 1963).
Moore, D. G., Investigation of shallow reference cavities for high-temperature emittance measurements (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1963), NASA Spec. Publ. SP–31, Session V, Paper 52, p. 515 (Dec. 1963).
Moore, G. A., Direct quantitative analysis of photomicrographs by a digital computer, Phot. Sci. Eng. **8**, No. 3, 152–161 (May–June 1964).
Mordfin, L., Hasley, N., Programmed maneuver-spectrum fatigue tests of aircraft beam specimens, ASTM Spec. Tech. Publ. No. 338, pp. 251–272 (Sept. 1963).
Morgan, A. H., Frequency and time broadcast services of the National Bureau of Standards, Proc. ISA 17th Annual Automation Conf. and Exhibit, New York, N.Y., Oct. 15–18, 1962, Pt. I, Paper 1.1.62, 9 pages (1962).
Motz, J. W., Placious, R. C., Large-angle inelastic scattering of 500-keV electrons, Phys. Rev. **132**, No. 3, 1120–1122 (Nov. 1963).
Motz, J. W., Placious, R. C., Dick, C. E., Coulomb scattering without atomic excitation for 50-, 100-, 200-, and 400-keV electrons, Phys. Rev. **132**, No. 6, 2258–2561 (Dec. 15, 1963).
Murphey, W. M., Chin, J., Intercomparisons of the standard thermal-neutron flux density of the National Bureau of Standards (Proc. Symp. Neutron Detection, Dosimetry and Standardization, International Atomic Energy Agency, Atomic Energy Research Establishment, Harwell, England, Dec. 10–14, 1962), book, Neutron Dosimetry II, 513–521 (International Atomic Energy Agency, Vienna, 1963).
Nakagawa, Y., Earnshaw, K. B., Experiments on self-ionizing shock waves in a magnetic field, book, Compt. Rend. VI^{e} Conf. Intern. sur les Phenomenes D'Ionisation dans les Gaz, ed. P. Hubert and E. Cremieu-Alcan, **IV**, 303–309 (S.E.R.M.A., Publ. Co., Paris, France, 1963).
Nason, M. E., Radio propagation quality in the North Atlantic Area 1953–1960, AGARDograph 59, The Effect of Disturbances of Solar Origin on Communications, ed. G. J. Gassman, pp. 287–291 (Pergamon Press, Inc., London, England, 1963).
Nesenbergs, M., Binary error probability due to an adaptable fading model, IEEE Trans. Commun. Syst. **CS–12**, No. 1, 64–73 (Mar. 1964).

Nesenbergs, M., Comparison of the 3-out-of-7 ARQ with Bose-Chaudhuri-Hocquenghem coding systems, IEEE Trans. Commun. Syst. **CS–11**, No. 2, 202–212 (June 1963).
Nettleton, R. E., Antireciprocity and memory in the statistical approach to irreversible thermodynamics, J. Chem. Phys. **40**, No. 1, 112–116 (Jan. 1964).
Nettleton, R. E., Foundations of the Callaway theory of thermal conductivity, Phys. Rev. **132**, No. 5, 2032–2038 (Dec. 1, 1963).
Nettleton, R. E., Inertial effects in the phenomenological theory of thermal diffusion in liquids, Il Nuovo Cimento **28**, Serie X, 952–969 (Dec. 7, 1962).
Newman, E. S., Berman, H. A., Calorimetry of portland cement. II. Application of various heat-of-solution procedures to determinations of the heat of hydration, ASTM Proc. 63, 852–860 (1963).
Newman, M., A complete description of the normal subgroups of genus one of the modular group, Am. J. Math. **86**, 17–24 (1964).
Newman, M., Free subgroups and normal subgroups of the modular group, Ill. J. Math. **8**, No. 2, 262–265 (1964).
Newman, M., Normal congruence subgroups of the modular group, Am. J. Math. **85**, No. 3, 419–427 (1963).
Newman, M., Normal congruence subgroups of the $t \times t$ modular group, Bull. Am. Math. Soc. **69**, No. 5, 719–720 (Sept. 1963).
Newman, M., On a problem of G. Sansone, Ann. Mat. **LXV**, 27–34 (1964).
Newman, S. B., Fletcher, D., Soft X-ray microscopy of paper, TAPPI **47**, No. 4, 177–180 (Apr. 1964).
Newman, S. B., Greenfeld, S. H., Projection X-ray microscopy of roofing materials, Mater. Res. Std. **3**, No. 11, 893–898 (Nov. 1963).
Nimeroff, I., Colorimetry in paraforpal fields: I. Color-matching functions, J. Opt. Soc. Am. **54**, No. 6, 824–832 (June 1964).
Nimeroff, I., Colorimetry in paraforpal fields: II. Additivity failure, J. Opt. Soc. Am. **54**, No. 6, 833–838 (June 1964).
Nimeroff, I., Field trial of the 1959 CIE supplementary standard observer proposal, J. Opt. Soc. Am. **54**, No. 5, 696–704 (May 1964).
Norton, K. A., Should the conventional definition of mismatch loss be abandoned? Proc. IEEE **52**, 710 (June 1964).
Norton, R. B., A theoretical study of the Martian ionosphere, book, Advances in the Astronautical Sciences and the Exploration of Mars **15**, 533–542 (Western Periodicals, Calif., 1963).
Noyce, R. H., Mosburgh, E. R., Garfinkel, S. B., Caswell, R. S., Absolute calibration of the National Bureau of Standards photoneutron source: III. Absorption in a heavy water solution of manganous sulfate, J. Nucl. Eng. **17**, No. 7, 313–319 (1963).
Ochs, G. R., Further observations of synchrotron radiation decay, J. Geophys. Res. **69**, No. 5, 1014–1016 (Mar. 1, 1964).
Ochs, G. R., The large 50 Mc/s dipole array at Jicamarca radio observatory, Program and Digest 1963 IEEE Prof. Group Ant. and Prop. Symp. Space Telecommunications, July 9–11, 1963, Boulder, Colo., pp. 237–241 (July 1963).
Ogburn, F., Myklebust, R. L., Galvanic currents observed during outdoor exposure of an iron-nickel cell, 50th Annual Tech. Proc. American Electroplaters Society, pp. 24–28 (1963).
Ogburn, F., Methods of testing, book, Modern Electroplating, pp. 661–697 (John Wiley & Sons, Inc., New York, N.Y., 1963).
Ogburn, F., Newton, C. J., Relation of partial (110) pole figures to thickness and microstructure of electrodeposited copper, J. Electrochem. Soc. **110**, No. 11, 1148–1150 (Nov. 1963).
Ogburn, F., Paretzkin, B., Peiser, H. S., Pseudopentagonal twins in electrodeposited copper dendrites, Acta Cryst. **17**, 774–775 (1964).
Okabe, H., Intense resonance line sources for photochemical work in the vacuum ultraviolet region, J. Opt. Soc. Am. **54**, No. 4, 478–481 (Apr. 1964).
Okabe, H., Becker, D. A., Vacuum ultraviolet photochemistry. VII. Photolysis of *n*-butane, J. Chem. Phys. **39**, No. 10, 2549–2555 (Jan. 1964).
Olien, N. A., An operational information retrieval system in the field of cryogenics (Proc. 26th Annual American Documentation Institute Meeting, Oct. 1963), book, Automation and Scientific Communication, pp. 157–178 (Am. Documentation Inst., 1963).
Olsen, H., Opening angles of electron-positron pairs, Phys. Rev. **131**, No. 1, 406–415 (July 1, 1963).
Olsen, L. O., Some recent developments in noble metal thermocouples, Am. Soc. Auto. Engrs. Paper No. 750A, p. 10 (Sept. 1963).
Olver, F. W. J., Error analysis of Miller's recurrence algorithm, Math. Computation **18**, No. 85, 65–74 (Jan. 1964).

Olver, F. W. J., Error bounds for asymptotic expansions in turning-point problems, J. Soc. Ind. Appl. Math. **12**, No. 1, 200–214 (Mar. 1964).
Olver, F. W. J., Error bounds for first approximations in turning-point problems, J. Soc. Ind. Appl. Math. **11**, No. 3, 748–772 (Sept. 1963).
Ordway, F., A condensation model producing crystalline or amouphous tetrahedral networks, Science **143**, No. 3608, 800–801 (Feb. 1964).
Otto, E. M., Equilibrium pressure of oxygen over Mn_2O_3-Mn_3O_4 at various temperatures, J. Electrochem. Soc. **111**, No. 1, 88–92 (Jan. 1964).
Paabo, M., Robinson, R. A., The standard potential of the silver-silver chloride electrode in 10 and 15% mannitol at 25°, J. Phys. Chem. **67**, No. 12, 2861–2862 (Dec. 1963).
Paquette, D. R., Wiese, W. L., Data-processing system for the automatic transformation of observed plasma intensities into their radial distribution, Appl. Opt. **3**, 291–295 (Feb. 1964).
Parker, M. S., Kransnansky, V. J., Achhammer, B. G., Effects of composition and irradiation on the glass transition temperature of methyl methacrylate-styrene copolymers, J. App. Polymer Sci. **8**, 1825–1838 (1964).
Parker, R. L., Anderson, R. L., Hardy, S. C., Growth and evaporation kinetics and surface diffusion of K and Hg crystal whiskers, Appl. Phys. Letters **3**, No. 6, 93–95 (Sept. 15 1963).
Parker, R. L., Krinsky, A., Electrical resistance-strain characteristics of thin evaporated metal films, J. Appl. Phys. **34**, No. 9, 2700–2708 (Sept. 1963).
Paul, A. K., Wright, J. W., Electron density profile analysis of topside sounder ionograms, J. Geophys. Res. **69**, No. 7, 1431–1435 (Apr. 1, 1964).
Paul, A. K., Wright, J. W., Some results of a new method for obtaining ionospheric $N(h)$ profiles and their bearing on the structure of the lower F region, J. Geophys. Res. **68**, No. 19, 5413–5420 (Oct. 1, 1963).
Peavy, B. A., Eubanks, A. G., Periodic heat flow in a hollow cylinder rotating in a furnace with a viewing port (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1963), NASA Spec. Publ. SP–31, Session V, Paper 56, pp. 553–564 (Dec. 1963).
Peiser, H. S., Levine, E. P., The characterization of large single crystals by high-voltage X-ray Laue photographs (Proc. 11th Annual Conf. Application of X-ray Analysis, Aug. 1962), book, Advances in X-ray Analysis 6, 158–163 (Plenum Press, Inc., New York, N.Y., 1963).
Perloff, A., The crystal structure of 1-ethyl decaborane, Acta Cryst. **17**, 332 (1964).
Peterson, A. E., An experimental 350-kv, 1-picofarad air capacitor, IEEE Trans. Paper No. 63–926, No. 71, pp. 129–131 (Mar. 1964).
Peterson, R. L., Discussion of spin-spin relaxation formulae and experiments, Phys. Letters **8**, No. 3, 158–159 (Feb. 1964).
Pfleger, J., Schmidt-Rohr U., Speigel, V., Turek, P., Zuckschwerdt W., Form and angular distribution of proton groups at about Q=0 Mev in the proton spectra of (d,p) reactions of heavy nuclei, Nuclear Phys. **48**, No. 1, 22–32 (Sept. 1963).
Piermarini, G. J., Block, S., Radial distribution study of vitrious borium boroscilicate, book, Advances in Glass Technology, pt. 2, pp. 44–46 (Plenum Press, Inc., New York, N.Y., 1963).
Piermarini, G. J., Weir, C. E., Allotropy in some rare-earth metals at high-pressure, Science **144**, No. 3614, 69–71 (Apr. 3, 1964).
Pollack, G. L., Pollack, A. A., Absorption spectra of diatomic molecules in liquid and crystalline rare gases, book, Developments in Applied Spectroscopy, ed. J. E. Forrette and E. Lanterman, 3, 376–382 (Plenum Press, Inc., New York, N.Y., 1964).
Pope, J. H., An explanation for the apparent polarization of some geomagnetic micropulsations (Pearls), J. Geophys. Res. **69**, No. 3, 399–405 (Feb. 1, 1964).
Powers, J., VanValkenberg, A., Polymer compression: visual observations on stressed biaxially oriented nylon 66, J. Polymer Sci. **B2**, No. 5, 533–536 (May 1964).
Prats, F., Fano, U., Metastable levels in the continuum and the independent particle model (Proc. 3d Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963), book, Atomic Collision Processes, ed. M. R. C. McDowell, pp. 600–605 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).
Prausnitz, J. M., Thermodynamic representation of high-pressure vapour-liquid equilibria, Chem. Eng. Sci. **18**, 613–630 (1963).
Pummer, W. J., Wall, L. A., 1,2.2-trifluorovinyl phenyl ether and 2,3,4,5,6-pentafluorophenyl 1,2,2-trifluorovinyl ether and their polymers, SPE Trans. **3**, No. 3, 220–224 (July 1963).
Purcell, J. R., Payne, E. G., High-field liquid H_2-cooled aluminum-wound magnet, Rev. Sci. Instr. **34**, No. 8, 893–897 (Aug. 1963).

Quinn, F. A., Jr., Powers, J., Measurement of a maximum in the isothermal crystallization rate-temperature curve for polypentene-1, J. Polymer Sci. **B1**, No. 7, 341–344 (July 1963).

Radford, H. E., Synthesis of diatomic radicals, J. Chem. Phys. (Commun.) **40**, No. 9, 2732–2733 (May 1, 1964).

Ramaley, D., Calibration of potentiometers by resistance bridge methods, Instr. Control Systems **37**, No. 1, 106–108 (Jan. 1964).

Randall, E. B., Jr., Interlaboratory evaluation of procedures for tongue-tearing strength of woven fabrics, Mater. Res. Std. **4**, No. 2, 53–61 (Feb. 1964).

Rebbert, R. E., Primary processes in the photolysis of ethyl nitrate, J. Phys. Chem. **67**, No. 9, 1923–1925 (Sept. 1963).

Rebbert, R. E., Ausloos, P. J., Complicating factors in the gas phase photolysis of azomethane, J. Phys. Chem. **67**, No. 9, 1925–1928 (Oct. 1963).

Rebbert, R. E., Ausloos, P., The reaction of methyl radicals with dimethylmercury, J. Am. Chem. Soc. **86**, No. 10, 2068–2069 (May 20, 1964).

Rebbert, R. E., Ausloos, P., The reactions of methyl radicals in the solid-, liquid-, and gas-phase photolysis of dimethylmercury, J. Am. Chem. Soc. **85**, No. 20, 3086–3089 (Dec. 1963).

Reese, R. M., Harllee, F. N., Mass spectrometry, Anal. Chem. **36**, No. 5, 278R–295R (Apr. 1964).

Reid, G. C., A diffusive model for the initial phase of a solar proton event, J. Geophys. Res. **69**, 2659–2667 (June 1964).

Reid, G. C., Physical processes in the *D*-region of the ionosphere, Rev. Geophys. **2**, No. 2, 311–333 (May 1964).

Reid, G. C., Bailey, D. K., Leinbach, H., On the height distribution of the ratio of negative ion and electron densities in the lowest ionosphere, J. Atmospheric Terrest. Phys. **26**, No. 1, 145–147 (Jan. 1964).

Reid, M. A., Lloyd, J. A., Note on observations on reference electrodes for fused salt systems, Rev. Sci. Instr. **34**, No. 8, 940–941 (Aug. 1963).

Rhodes, I., Syntactic integration carried out mechanically, Inform. Storage and Retrieval **1**, 215–219 (1963).

Rhodes, I., The method for mechanical translation used by the National Bureau of Standards group and the structure of its machine glossary (Proc. 26th Annual American Documentation Institute Meeting, Oct. 1963), book, Automation and Scientific Communication, pp. 23–24 (Am. Documentation Inst., 1963).

Richardson, A. C. B., Costrell, L., Use of transistors in Van de Graaff source leak controls, Nucl. Instr. Methods **24**, No. 1, 129–130 (July 1963).

Richardson, J. M., Brockman, J. F., The U.S. basis of electromagnetic measurements, IEEE Spectrum **1**, No. 1, 129–138 (Jan. 1964).

Richmond, J. C., Editor's preface and foreword to book, Measurement of Thermal Radiation Properties (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1962), NASA Spec. Publ. SP–31, p. iii (Dec. 1963).

Richmond, J. C., Harrison, W. N., Shorten, F. J., An approach to thermal emittance standards (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1963), NASA Spec. Publ. SP–31, Session IV, Paper 41, pp. 403–424 (Dec. 1963).

Riddle, J. L., Constants of the interpolation formula for platinum resistance thermometers, Proc. Advisory Committee on Thermometry to the Intern. Bureau of Weights and Measures, 6th Session, pp. 198–201 (Sept. 26–27, 1962).

Riddle, J. L., Temperature measurements below 1000 °K (Symp. Measurement of Thermal Radiation Properties of Solids, Dayton, Ohio, Sept. 5–7, 1963), NASA Spec. Publ. SP–31, Session I, Paper 2, pp. 11–12 (Dec. 1963).

Ries, F. X., High frequency microvolt measurements, ISA Preprint, pp. 37.2.63-1–37.2.63-5 (Sept. 1963).

Rishbeth, H., A time-varying model for the ionospheric F_2 layer, J. Atmospheric Terrest. Phys. **26**, No. 6, 657–685 (June 1964).

Risley, A. S., Bussey, H. E., Ferromagnetic resonance relaxation, wide spin wave coverage by ellipsoids, J. Appl. Phys. **35**, pt. 2, No. 3, 896–897 (Mar. 1964).

Roach, F. E., Nightglow, Adv. Electron. and Electron Phys. **18**, 1–44 (1963).

Roach, F. E., Photometric observations of the airglow during the IQSY, IQSY Instruction Manual No. 5, Airglow, pt. 1, 1–24 (IQSY Secretariat, London, England, 1963).

Roach, F. E., Roach, J. R., Stable 6300 A auroral arcs in mid-latitudes, Planetary Space Sci. **11**, 523–545 (May 1963).

Robbins, R. F., Ludtke, P. R., Review of static seals for cryogenic systems, J. Spacecraft Rockets **1**, No. 3, 253–259 (May–June 1964).

Robertson, A. F., Surface flammability measurements by the radiant panel methods, ASTM Proc. 62, 33–46 (1962).

Robinson, R. A., Peiperl, A., The ionization constant of m-nitrophenol from 5 to 50°, J. Phys. Chem. **67**, No. 12, 2860–2861 (Dec. 1963).

Robinson, R. A., Peiperl, A., The ionization constants of *o*-nitrophenol and 4-nitro-m-cresol from 5 to 60°, J. Phys. Chem. **67**, No. 8, 1723–1724 (Aug. 1963).

Rohrlich, F., Pecker, C., Highly ionized atoms: the configurations s^2p^n (n=1,2,4,5), Astrophys. J. **138**, No. 4, 1246–1261 (Nov. 15, 1963).

Rosenberg, N. W., Edwards, H. D., Wright, J. W., Ionospheric winds: motions into nigth and sporadic *E* correlations (Proc. 4th Intern. Space Science Symp., Warsaw, June 4–10, 1963), book, Space Research, ed. P. Muller, IV, 171–181 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Rosenstock, H. M., Dibeler, V. H. Harllee F. N., Initial preparation and metastable transitions in mass spectra, J. Chem. Phys. **40**, No. 2, 591–594 (Jan. 15, 1964).

Rosenthal, D., Hetzer, H. B., Bates, R. G., Salt effects and medium effects on indicator acid-base equilibria in a methanol-water solvent, J. Am. Chem. Soc. **86**, No. 4, 549–554 (Feb. 20, 1964).

Rosholt, J. N., Garner, E. L., Shields, W. R., *F* actionation of uranium isotopes and daughter products in weathered granite and uranium-bearing sandstone, Wind River basin region, Wyoming, U.S. Geol. Survey Prof. Paper 501–B, pp. 884–887 (1964).

Ross, G. S., Dixon, H. L., Frolen, L., Termini, D. J., Polymorphism in isopropyl alcohol, Science **141**, No. 3585, 1043–1044 (Sept. 1963).

Ross, G. S., Glasgow, A. R., Jr., A simplified freezing point apparatus, Anal. Chem. **36**, No. 3, 700 (Mar. 1964).

Roth, R. S., Waring, J. L., Ixiolite and other polymorphic types of $FeNbO_4$, Am. Mineralogist **49**, Nos. 3 & 4, 242–246 (Mar.–Apr. 1964).

Roth, R. S., Waring, J. L., Synthesis and stability of bismutotantalite, stibiotantalite and chemically similar ABO_4 compounds, Am. Mineralogist **48**, Nos. 11 & 12, 1348–1356 (Nov.–Dec. 1963).

Roth, R. S., Waring, J. L., Levin, E. M., Polymorphism of ABO_3-type rare earth borate solid solutions (Proc. 3d Rare Earth Research Conf., Apr. 2–24, 1963), book, Rare Earth Research, Chapter on Structure of Rare Earth Compounds, pp. 1030–1055 (Gordon and Breach Science Publ., Inc., New York, N.Y., 1964).

Rubin, R. J., A classical model for the study of isotope effects in energy exchange and particle exchange reactions, J. Chem. Phys. **40**, No. 4, 1069–1077 (Feb. 15, 1964).

Rubin, R. J., Momentum autocorrelation functions and energy transport in harmonic crystals containing isotopic defects, Phys. Rev. **131**, No. 3, 964–989 (Aug. 1, 1963).

Rubin, S., Hall generators: what, why and how much? IEEE Intern. Conv. Record, pt. 8, p. 74 (Mar. 1964).

Ruff, A. W., Jr., Open-probe thermocouple control of radio-frequency heating, Rev. Sci. Instr. **35**, No. 6, 760–761 (June 1964).

Ruff, A. W., Jr., Kushner, L. M., Observations on dislocation loops in deformed copper, Proc. Conf. Relation Between the Structure and Mechanical Properties of Metals, National Physical Laboratory, Teddington, Middlesex, England 1, 146–156 (1963).

Ruffa, A. R., Theory of the electronic susceptibilities of Stoichiometric rutile (TiO_2), Phys. Rev. **133**, No. 5A, 1418–1426 (Mar. 2, 1964).

Russell, D. H., An unmodulated twin channel microwave attenuation measurement system, ISA Preprint, pp. 37.3.63-1–37.3.63-17 (Sept. 1963).

Ruthberg, S., Conduction-cooled, concentric sphere, glass trap, Vacuum **14**, No. 1, 11 (Jan. 1964).

Sarachman, T. N., The microwave spectrum of normal propyl chloride, J. Chem. Phys. **39**, No. 2, 469–473 (July 1963).

Saunders, C. J., Method for comparing two nearly equal potentials directly in parts per million, Rev. Sci. Instr. **34**, No. 12, 1452–1453 (Dec. 1963).

Schaffer, G. E., Beatty, R. W., Correction to a method for measuring the directivity of directional couplers, IEEE Trans. Microwave Theory Tech. **MTT–12**, No. 3. 361 (May 1964).

Schaffer, R., Synthesis of higher ketoses by aldol reactions. II. Unsubstituted heptuloses, J. Org. Chem. **29**, 1471–1473 (June 1964).

Schaffer, R., The isomerization of D-manno-3-heptulose by alkali, J. Org. Chem. **29**, 1473–1475 (June 1964).

Scheer, M. D., Fine, J., Kinetics of desorption. III. Rb^+, K^+, and Na^+ on rhenium J. Chem. Phys. **39**, No. 7, 1752–1755 (Oct. 1963).

Scheer, M. D., Klein, R., Reaction of ground state oxygen atoms with condensed olefins, Science **144**, No. 3623, 1214 (Apr. 1964).

Schmeltekopf, A. S., Broida, H. P., Short-duration visible afterglow in helium, J. Chem. Phys. **39**, 1261–1268 (Sept. 1963).

Schneider, S. J., Discrepancy in conversion of early melting-point temperatures, J. Am. Ceram. Soc. **46**, No. 7, 354–355 (1963).

Schooley, J. F., Hosler, W. R., Cohen, M. L., Superconductivity in Semiconducting $SrTiO_3$, Phys. Rev. Letters **12**, No. 17, 474–475 (Apr. 1964).

Schweitzer, W. G., Jr., Hyperfine structure and isotope shifts in the 2537-A line of mercury by a new interferomertic method, J. Opt. Soc. Am. **53,** No. 9, 1055–1072 (Sept. 1963).

Schweitzer, W. G., Jr., Wavelength passed by Hg^{198} Zeeman-split absorption filter, J. Opt. Soc. Am. **53,** No. 11, 1250–1252 (Nov. 1963).

Schweitzer, W. G., Jr., Kessler, K. G., Wavelength of Hg^{198} Zeeman filter relative to that of the 2537-A absorption line of an atomic beam, J. Opt. Soc. Am. **53,** No. 12, 1382–1388 (Dec. 1963).

Scott, A. H., Techniques for using the air-gap method for the precise determination of the dielectric constant and loss angle of solid-disk specimens (Proc. Conf. Electric Insulation), 1963 Annual Report, Natl. Acad. Sci.-Natl. Res. Council Publ. 1141, pp. 74–76 (1964).

Scott, R. B., Recent progress in cryogenic engineering, Proc. Mountain States Navy Research and Development Clinic, Raton, N. M., Sept. 28–29, 1961, pp. D1–D4 (Raton, Communications and Electronics Foundation, 1963).

Scott, W. W., A new high voltage calibration facility at the National Bureau of Standards, Boulder, ISA 1963 Proc. Paper No. 7.2.63 (1963).

Scribner, B. F., Margoshes, M., Emission spectrometry, Anal. Chem. **36,** No. 5, 329R–343R (1964).

Selby, M. C., Pulsed and CW sinusoidal voltage and current measurements, Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, **XIII**, 92–100 (1964).

Shapley, A. H., Abbreviated calendar record, January–February 1964, IQSY Notes, **7,** 19–25 (May 1964).

Shapley, A. H., IQSY Instruction Manual. No. 1. World days, 32 pages IQSY Secretariat, London, England (July 1963).

Shapley, A. H., Resurgence of solar and geomagnetic activity in September and October 1963 IQSY Notes **5,** 10 (Dec. 1963).

Shapley, A. H., The ionosphere, U.S. Information Agency Voice of America Forum Series on Space Science, Lecture No. **7,** 6 pages (1963).

Shapley, A. H., World days program, IQSY Notes, **5,** 27–30 (Dec. 1963); **6,** 27–32 (Mar. 1964); 7, 13–15 (May 1964).

Shapley, A. H., Lincoln, J. V., International geophysical calendar 1963, IQSY Notes **4,** 34 (Sept. 1963).

Shapley, A. H., Lincoln, J. V., International geophysical calendar for the years of the quiet sun 1964–1965, J. Radio Res. Labs. Japan **10,** 185–192 (Mar. 1963); IUGG Chronicle **50,** 171–174 (July 1963); URSI Inform. Bull. **139,** 64–71 (July–Aug. 1963); IG Bull. **74,** 15–18 (Aug. 1963); Weatherwise **16,** 160–161 (Aug. 1963); J. Geophys. Res. **68,** 5318–5323 (Sept. 15, 1963); Trans. Am. Geophys. Union **44,** 821–824 (Sept. 1963); J. Atmospheric Terrest. Phys. **26,** No. 1, 151–157 (Jan. 1964); Nature **201,** 11–13 (Jan. 4, 1964).

Shepley, L. C., Bestul, A. B., Deuterium isotope effect on glass transformation temperatures of aqueous inorganic solutions, J. Chem. Phys. **39,** No. 3, 680–687 (Aug. 1, 1963).

Shuler, K. E., ed., Ionization of High Temperature Gases, Volume XII of Progress in Astronautics and Aeronautics, Academic Press, Inc., New York, N.Y., 1963.

Shumaker, J. B., N^{+}_{2} oscillator strength from arc spectroscopic measurements using an analog computer, Proc. 6th Intern. Symp. Ionization Phenomena in Gases **VII**, No. 15, 311–313 (June 1964).

Shumaker, J. B., Yokley, C. R., The use of an analog computer in side-on arc spectroscopy, Appl. Opt. **3,** No. 1, 83–87 (Jan. 1964).

Simpson, J. A., Anomalous transmission of rare gases for electrons of sub-excitation energies (Proc. 3d Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963), book, Atomic Collision Processes, ed. M. R. C. McDowell, pp. 128–134 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).

Simpson, J., Fano, U., Classification of resonances in the electron scattering cross section of Ne and He, Phys. Rev. Letters **11,** No. 4, 158–159 (Aug. 1963).

Simpson, J. A., Kuyatt, C. E., Mielczarek, S. R., Electron monochromator utilizing the scattering resonance in helium, Rev. Sci. Instr. **34,** No. 12, 1454–1455 (Dec. 1963).

Simpson, J. A., Mielczarek, S. R., Determination of electronic energy levels of molecules by low-energy electron-impact spectroscopy, J. Chem. Phys. **39,** No. 6, 1606–1607 (Sept. 1963).

Simpson, J. A., Mielczarek, S. R., Cooper, J., Observation of optically forbidden transitions in the continuum of the rare gases by electron energy loss measurements, J. Opt. Soc. Am. **54,** No. 2, 269–270 (Feb. 1964).

Sligh, J., Brenner, A., Galvanostalametry, a new technique based on the negative pressure of liquids, for investigating electrochemical phenomena at an electrode, J. Electrochem. Soc. **110,** No. 11, 1136–1142 (Nov. 1963).

Smith, C. R., Bound states in a Debye-Huckel potential, Phys. Rev. **134**, No. 5A, A1235–A1237 (June 1964).
Smith, J. C., Fenstermaker, C. A., Shouse, P. J., Behavior of filamentous materials subjected to high speed tensile impact, ASTM Spec. Tech. Publ. No. 336, pp. 47–69 (Oct. 1963).
Smith, J. C., Fenstermaker, C. A., Shouse, P. J., Stress-strain relationships in yarns subjected to rapid impact loading. 10. Stress-strain curves obtained by impact with rifle bullets, Textile Res. J. **33**, No. 11, 919–934 (Nov. 1963).
Smith, L. L., Alexander, R. B., Methods of calibration of airglow photometers at Fritz Peak Observatory, IQSY Instruction Manual. No. 5: Airglow, Pt. II, pp. 25–36 (IQSY Secretariat, London, England, 1963).
Smith, R. V., Choking two-phase flow of hydrogen: some idealized solutions, Proc. Nuclear Propulsion Conf., Atomic Energy Commission, pp. 115–125 (AEC, Oak Ridge, Tenn., July 1963).
Smith, R. V., Edmonds, D. K., Brentari, E. G. F., Richards, R. J., Analysis of the frost phenomena on a cryo-surface (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), book, Advances in Cryogenic Engineering 9, Paper B–7, 88–97 (Plenum Press, Inc., New York, N.Y., 1964).
Snodgrass, R. J., Bennett, L. H., Knight-shifts and line widths of the nuclear magnetic resonance of Pb^{207} in lead-indium alloys, Phys. Rev. **132**, No. 4, 1465–1474 (Nov. 15, 1963).
Snodgrass, R. J., Bennett, L. H., Nuclear magnetic resonance in lead alloys, Phys. Rev. **134**, No. 5A, A1294 (June 1, 1964).
Spaulding, A. D., Determination of error rates for narrow-band communication of binary-coded messages in atmospheric radio noise, Proc. IEEE **52**, No. 2, 220–221 (Feb. 1964).
Stair, R., Schneider, W. E., Standards, sources, and detectors in radiation measurements, Symp. Thermal Radiation of Solids, Session III. Measurement Techniques, San Francisco, Calif., Mar. 4–6, 1964, Paper 3 (1964).
Stair, R., Schneider, W. E., Jackson, J. K., A new standard of spectral irradiance, Appl. Opt. **2**, No. 11, 1151–1154 (Nov. 1963).
Stansburg, C., One year trial for new voltmeter standards, Mag. Std. **34**, No. 8, 240–241 (Aug. 1963).
Stark, M. C., Computer simulation of traffic on nine blocks of a city street (Proc. 41st Annual Meeting Highway Research Board, Jan. 8–12, 1962), Highway Res. Board Bull. 356, Publ. No. 1051, p. 40 (Natl. Acad. Sci.-Natl. Res. Council, Washington, D.C., 1962).
Steiner, B., Seman, M. L., Branscomb, L. M., Energy dependence for the photodetachment of I^- near threshold (Proc. 3d Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, 1963), Book, Atomic Collision Processes, ed. M. R. C. McDowell, pp. 537–542 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).
Steinert, L. A., Ferromagnetic resonance and shape-dependent effects, J. Appl. Phys. **34**, No. 7, 2106–2107 (July 1963).
Stevens, M. E., Urban, G. H., Training a computer to assign descriptors to documents: experiments in automatic indexing and experiments in information correlation, Proc. Spring Joint Computer Conf., Washington, D.C., 1964, 25, 563–577 (Spartan Book, Baltimore, Md., 1964).
Stewart, J. W., Dielectric polarizability of fluid parahydrogen, J. Chem. Phys. 40, 3297–3306 (June 1964).
Stewart, R. B., The quest for design data, Symp. The Role Cryogenics is Playing in Expanding Mechanical Engineering, Am. Soc. Refrigerating and Air Conditioning Engineers, New York, N.Y., Feb. 11–14, 1964, pp. 13–24 (1964).
Stewart, R. B., Timmerhaus, K. D., The correlation of thermodynamic properties of cryogenic fluids (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), book, Advances in Cryogenic Engineering 9, Paper A–3, 20–27 (Plenum Press, Inc., New York, N.Y., 1964).
Stiehler, R. D., One man's opinion—a common language (nomenclature for rubbers), Rubber World **148**, No. 3, 119 (June 1963).
Stovall, T., Empirical rules for predicting ground-state spins of light nuclei, Phys. Rev. **133B**, No. 2B, B268–B269 (Feb. 27, 1964).
Stovall, T., Danos, M., Note on the 4-body system, Phys. Letters **7**, No. 4, 278–281 (Oct. 23, 1963).
Straus, S., Wall, L. A., Pyrolysis of new fluoropolymers, SPE Trans. **4**, No. 1, 56–60 (Jan. 1964).
Straus, S., Wall, L. A., Pyrolysis of polytrifluoroethylene: influence of gamma radiation and alkali treatment, SPE Trans. **4**, No. 1, 61–65 (Jan. 1964).
Streever, R. L., Nuclear magnetic relaxation of the impurity nucleus in dilute ferromagnetic alloys, Phys. Rev. **134**, No. 6A, A1612–A1617 (June 1964).

Streever, R. L., Bennett, L. H., Line shapes, saturation behavior, and temperature studies in the nuclear resonance of nickel, Phys. Rev. **131**, No. 5, 2000–2009 (Sept. 1963).

Streever, R. L., Uriano, G. A., Nuclear magnetic resonances of ^{69}Ga and ^{71}Ga in gallium-substituted yttrium iron garnet, Phys. Rev. Letters **12**, No. 22, J516–1–3–J516–3–3 (June 1, 1964).

Strobridge, T. R., Mann, D. B., Modern methods of analysis for design of cryogenic equipment and processes, Am. Soc. Refrigerating and Air Conditioning Engineers Symp., The Role Cryogenics Is Playing in Expanding Mechanical Engineering, Am. Soc. Refrigerating and Air Conditioning Engineers, New York, N.Y., Feb. 11–14, 1964, pp. 25–37 (1964).

Sugar, G. R., Radio propagation by reflection from meteor trails, Proc. IEEE **52**, No. 2, 116–136 (Feb. 1964).

Sugar, J., Analysis of the third spectrum of praseodymium, J. Opt. Soc. Am. **53**, No. 7, 831–839 (July 1963).

Sutton, L. E., A method for localized variation of the paths of two paraxial rays, Appl. Opt. **2**, No. 12, 1275–1280 (Dec. 1963).

Swanson, N., Powell, C. J., Excitation of π electrons in polystyrene and similar polymers by 20-KeV electrons, J. Chem. Phys. **39**, No. 3, 630–634 (Aug. 1, 1963).

Swartzendruber, L. J., Four-point probe measurement of non-uniformities in semiconductor sheet resistivity, Solid State Electron. **7**, 413–422 (1964).

Sze, W. C., Harris, F. K., Kusters, N. L., Petersons, O., Moore, W. J. M., An international comparison of voltage transformer calibrations to 350 KV, IEEE Trans. Commun. and Electron. Paper No. 63–992, No. 70, 13–18 (Jan. 1964).

Takuma, H., Jennings, D. A., Coherent Raman effect in the off-axis Raman resonator, Appl. Phys. Letters **4**, No. 11, 185–186 (June 1964).

Taylor, J. K., Polarography as an analytical tool, J. Assoc. Offic. Agri. Chem. **47**, No. 1, 21–27 (Jan. 1964).

Taylor, L. S., Preparation of lantern slides, Health Phys. J. **9**, No. 10, 1009–1011 (Oct. 1963).

Taylor, L. S., Problems in the application of norms of external radiation, Symp. Personnel Dosimetry Techniques for External Radiation, Madrid, Spain, Apr. 1–5, 1963, pp. 35–47 (1963).

Taylor, W. L., Jean, A. G., VLF propagation, Proc. Mountain States Navy Research and Development Clinic, Raton, N. M., Sept. 28–29, 1961, pp. A45–A66 (Raton, Communications and Electronics Foundation, 1963).

Tchen, C. M., Collective correlation of plasma, Proc. 2d Conf. Electronics, Czechoslovak J. Phys. **XXI**, No. 5–6, 516–521 (Apr. 1962).

Thayer, G. D., Bean, B. R., Systematic atmospheric refraction errors of baseline-type radio tracking systems and methods of their correction, Proc. 1st Space Congress, Cocoa Beach, Fla., Apr. 1964.

Thomas, R. N., Microscopic-astrophysics and the development of astrophysical laboratories, Bull. Centre Intern. d'Astrophysique de l'Observatoire de Nice, No. 1, pp. 7–16 (Nice, France, 1964).

Thibault, R. J., Maki, A. G., Plyler, E. K., Broadening of the ν_3 lines of HCN due to argon, carbon dioxide, and hydrogen chloride, J. Opt. Soc. Am. **53**, No. 11, 1255–1258 (Nov. 1963).

Thompson, W. A., Willke, T. A., On an extreme rank sum test for outliers, Biometrika **50**, No. 3 & 4, 375–383 (Dec. 1963).

Tighe, N. J., Jet thinning devices for preparation of Al_2O_3 electron microscope specimens, Rev. Sci. Instr. **35**, No. 4, 520–521 (Apr. 1964).

Trees, R. E., $4f^3$ and $4f^25d$ configurations of doubly ionized praseodymium (Pr III), J. Opt. Soc. Am. **54**, No. 5, 651–657 (May 1964).

Tsang, W., Comparative rate measurements with a single-pulse shock tube, J. Chem. Phys. **40**, No. 4, 1171–1172 (Feb. 1964).

Tsang, W., Thermal decomposition of some *tert*-butyl compounds at elevated temperatures, J. Chem. Phys. **40**, No. 6, 1498–1505 (Mar. 1964).

VnaValkenberg, A., High pressure microscopy, book, High-Pressure Measurement, ed. A. A. Giardini and E. C. Lloyd, pp. 87–94 (Butterworth Inc., Wash., D.C., 1963).

VanValkenberg, A., Powers, J., Optical observations of pressures induced in polymers, J. Appl. Phys. **34**, No. 8, 2433–2434 (Aug. 1963).

VanZandt, T. E., Ionizing radiation and constitution of the atmosphere. Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, **XIII**, 158–164 (1964).

VanZandt, T. E., Calvert, W., Knecht, R. W., Goe, G. B., Evidence for field-aligned ionization irregularities between 400 and 1000 km above the earth's surface, book, Space Research, ed. W. Priester III, 271–273 (North Holland Publ. Co., Amsterdam, The Netherlands, 1963).

VanZandt, T. E., Knecht, R. W., The structure and physics of the upper atmosphere, book, Space Physics, pp. 166–225 (John Wiley & Sons, Inc., New York, N.Y., 1964).
Vinti, J. P., The spheroidal method for satellite orbits, Proc. Intern. Symp. Use of Artificial Satellites for Geodesy, pp. 12–16 (North Holland Publ. Co., Amsterdam, The Netherlands, 1963).
Vogler, L. E., A note on the attenuation function for propagation over a flat layered ground, IEEE Trans. Ant. Prop. **AP–12**, No. 2, 240–242 (Mar. 1964).
Wachtman, J. B., Jr., Mechanical and electrical relaxation in ThO_2 containing CaO, Phys. Rev. **131**, No. 2, 517–527 (July–Sept. 1963).
Wachtman, J. B., Jr., Doyle, L. R., Internal friction in rutile containing point defects, Phys. Rev. **135A**, 276 (1964).
Wait, J. R., An approach to the classification of electromagnetic surface waves, book, Radio Waves and Circuits by S. Silver, pt. I, pp. 86–95 (Elsevier Publ. Co., Princeton, N.J., 1963).
Wait, J. R., Comments on the paper "Obstacle gain and shadow loss," by G. H. Crenier, Microwave J. (Letter) **6**, No. 7, 83 (July 1963).
Wait, J. R., Electromagnetic scattering from a radially inhomogeneous sphere, Appl. Sci. Res. **10**, Sec. B, 441–450 (Jan. 1, 1963).
Wait, J. R., On phase changes in very-low-frequency propagation induced by an ionospheric depression of finite extent, J. Geophys. Res. **69**, No. 3, 441–445 (Feb. 1, 1964).
Wait, J. R., On the theory of Schumann resonances in the earth-ionosphere cavity, Can. J. Phys. **42**, 575–582 (Apr. 1964).
Wait, J. R., Review of mode theory of radio propagation in terrestrial waveguides, Rev. Geophys. **1**, No. 4, 481–505 (Nov. 1963).
Wait, J. R., Some remarks concerning nonreciprocity in radio propagation, IEEE Trans. Ant. Prop. **AP–12**, No. 3, 372–373 (May 1964).
Wait, J. R., The relation between VLF propagation and *D*-layer characteristics, IEEE Trans. Ant. Prop. **AP–12**, No. 2, 239–240 (Mar. 1964).
Wait, J. R., The theory of an antenna over an inhomogeneous ground plane, book, Electromagnetic Theory and Antennas, ed. E. C. Jordan, pt. 2, pp. 1079–1098 (Pergamon Press Inc., Oxford, England, 1963).
Wait, J. R., Transverse propagation of electromagnetic waves in a cylindrically stratified plasma, Proc. Radio Physics Symp., Univ. Calif., Los Angeles, Aug. 7–9, 1963, ed. J. Brandstatter (Holden-Day, Inc., San Francisco, Calif., 1964).
Wall, L. A., Brown, D. W., Radiation-induced polymerization at high pressures, J. Polymer Sci. **C2**, No. 4, 1151–1160 (1963).
Walsh, J. L., Shisha, O., The zeros of infrapolynomials with prescribed values at given points, Proc. Am. Math. Soc. **14**, No. 5, 839–844 (Oct. 1963).
Waring, J. L., Roth, R. S., Tetragonal phases of the general type $10M_2O_5 \cdot 90M_2O_5$ apparently isostructural with $Ta_2O_5N \cdot 2b_2O_5$, Acta Cryst. **17**, 455–456 (1964).
Warwick, C. S., Solar particles and interplanetary fields, books, Advances in the Astronautical Sciences 13, 666–681 (Western Periodicals, Calif., 1963).
Warwick, C. S., Lincoln, J. V., Relation of solar active regions at central meridian passage to ionospheric disturbance, AGARDograph 59, The Effect of Disturbances of Solar Origin on Communications, ed. G. J. Gassmann, pp. 229–233 (Pergamon Press Inc., London, England, 1963).
Washer, F. E., Darling, W. R., Optical T-bench method for measurement of optical path difference, SPE J. **1**, No. 6, 211–217 (Aug.–Sept. 1963).
Waterhouse, R. V., Radiation impedance of a source near reflectors, J. Acoust. Soc. Am. **35**, No. 8, 1144–1151 (Aug. 1963).
Weinstock, J., Cluster formulation of the exact equation for the evaluation of a classical many-body system, Phys. Rev. **132**, No. 1, 454–469 (Oct. 1, 1963).
Weinstock, J., Theory of irreversible processes in plasmas—derivation of a convergent kinetic equation from the generalized master equation, Phys. Rev. **133**, No. 3A, A673–A680 (Feb. 3, 1964).
Weinstock, J., The three-body scattering operator in non equilibrium statistical mechanics, Phys. Rev. **132**, No. 1, 470–482 (Oct. 1, 1963).
Weiss, A. W., Wave functions and oscillator strengths for the lithium iso-electronic sequence, Astrophys. J. **138**, No. 4, 1262–1276 (Nov. 15, 1963).
Weiss, A. W., Martin, J. B., First-order perturbation corrections to the Hartree-Fock approximation for helium, Phys. Rev. **132**, No. 5, 2118–2122 (Dec. 1, 1963).
Weiss, G., A simple derivation of the Faxen solution to the Lamm equation, J. Math. Phys. **5**, 675–676 (1964).
Wells, J. S., Daywitt, W. C., Miller, C. K. S., Measurement of effective temperatures of microwave noise sources, IEEE Trans. Instr. Meas. **IM–13**, No. 1, 17–28 (Mar. 1964).
West, E. D., Heating rate as a test of adiabatic calorimeters and the heat capacity of α-alumina, Trans. Faraday Soc. **59, Pt. 9**, 489, 2200–2203 (Sept. 1963).

Wexler, A., Humidity, ISA Transducer Compendium, pp. 502–508 (1963).
Wexler, A., The 1963 symposium on humidity and moisture, May 20–23, 1963, Washington, D.C., Intern. J. Heat Mass Transfer **7**, 275–277 (1964).
Whatley, L. S., Lippincott, E. R., VanValkenburg, A., Weir, C. E., Optical studies at high pressures, Science **144**, No. 3621, 968–976 (May 22, 1964).
White, J. A., An implication for lasers of an aspect of interference at high field strengths, Nature (Letter) **201**, No. 4922, 911–912 (Feb. 29, 1964).
White, J. A., Dependence of power output of a gas laser on the length and rate of excitation of the discharge, Appl. Phys. Letters **3**, No. 7, 107–109 (Oct. 1, 1963).
Wickoff, B. A., The establishment and maintenance of the unit of voltage at the NBS Boulder Laboratories, ISA 1963 Proc. Paper No. 28.2.63 (1963).
Wiese, W. L., Measurement of the cross section for elastic scattering of slow electrons by hydrogen atoms, Proc. VIth Intern. Conf. Ionization Phenomena in Gases, Paris, France, 1963, I, 5–8 (July 1963).
Wiese, W. L., Murphy, P. W., Shifts and widths of some stark broadended oxygen liens in an arc plasma, Phys. Rev. **131**, No. 5, 2108–2115 (Sept. 1963).
Witzgall, C., An all-integer programming algorithm with parabolic constraints, J. Soc. Ind. Appl. Math. **11**, No. 4, 855–871 (1963).
Woelfel, J. B., Paffenbarger, G. C., Sweeney, W. T., Some physical properties of organic denture base materials, J. Am. Dental Assoc. **67**, No. 4, 489–504 (Oct. 1963).
Woelfel, J. B., Paffenbarger, G. C., Sweeney, W. T., Strain release in complete dentures, J. Am. Dental Assoc. **67**, No. 2, 321 (Aug. 1963).
Wolfe, W. C., Differential dielectric apparatus for determining water added to solvents, Anal. Chem. **35**, 1884–1887 (Nov. 1963).
Wollin, H. F., Tomorrow's facilities for standards and measurements, Scale J. **50**, No. 9, 2 (June 1964).
Wood, G. B., A study of embrittlement of high strength steels by hydrogen isotopes. I. Testing of steel rings as specimens, a comparison of hydrogen and deuterium embrittlement, and permeation studies. II. A comparison of gas contents and hydrogen or deuterium embrittlement resulting from electroplating processes, J. Electrochem. Soc. **110**, No. 8, 867–885 (Aug. 1963).
Wright, J. R., Campbell, P. G., Fridinger, T. L., The effect of carbon-arc intensity on asphalt oxidation, J. Appl. Chem. (London) **14**, 30–35 (Jan. 1964).
Wright, J. R., Campbell, P. G., Fridinger, T. L., The relationship between intensity of carbon arc and asphalt oxidation, ASTM Spec. Tech. Publ. No. 347, pp. 3–20 (May 1964).
Wright, J. R., Minesinger, R. R., Velocity-depth relationship in microelectrophoresis cell for asphaltenes in nitromethane, J. Colloid Sci. (Letter) **18**, 802–804 (Oct. 1963).
Wright. J. W., Diurnal and seasonal variations of the atmosphere near the 100-kilometer level, J. Geophys. Res. **69**, 2851–2853 (June 1964).
Wright, J. W., Electron distribution in the ionosphere, Proc. URSI XIVth General Assembly, Tokyo, Japan, Sept. 1963, **XIII**, 206–222 (1964).
Wright, J. W., Ionosonde studies of some chemical releases in the ionosphere (Proc. NATO Advanced Study Institute, Sheikampen, Norway, Apr. 17–26, 1963), book, Electron Density Distribution in the Ionosphere and Exosphere, pp. 116–137 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).
Wright, J. W., On the implication of diurnal, seasonal and geographical variations in composition of high atmosphere from F-region measurements (Proc. NATO Advanced Study Institute, Sheikampen, Norway, Apr. 17–26, 1963), book, Electron Density Distribution in the Ionosphere and Exosphere, pp. 186–198 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).
Wright, J. W., The F-region seasonal anomaly, J. Geophys. Res. 68, No. 14, 4379–4381 (July 15, 1963).
Wright, J. W., Paul, A. K., Some results of a new method for obtaining ionospheric N(h) profiles with a bearing on the structure of the lower F region (Proc. NATO Advanced Study Institute, Sheikampen, Norway, Apr. 17–26, 1963), book, Electron Density Distribution in the Ionosphere and Exosphere, pp. 105–115 (North Holland Publ. Co., Amsterdam, The Netherlands, 1964).
Yee, K. W., Carpenter, R. J., Regulation of ionization gauge emission current to better than 0.05%, Rev. Sci. Instr. **34**, No. 10, 1101–1103 (Oct. 1963).
Youden, W. J., Mathematics and experimental science, Sci. Teacher **30**, No. 5, 23–26 (Sept. 1963).
Youden, W. J., Parable of the fisherman, Phys. Teacher **1**, No. 3, 120–121 (Sept. 1963).
Youden, W. J., Physical measurements and experiment design (Colloq. Intern. Centre Natl. Recherche Sci., Aug.–Sept. 1961), book, Le Plan d'Experiences, No. 100, p. 115 (Centre National de la Recherche Scientifique, Paris, France, 1963).
Youden, W. J., Statistics in its proper place, J. Wash. Acad. Sci. **54**, 53–57 (Mar. 1964).

Youden, W. J., The Fisheriana revolution in the technique of experimentation, Estadistica (Inter American Statistical Institute) **21**, No. 80, 524–527 (Sept. 1963).

Youden, W. W., Characteristics of programs for KWIC and other computer-produced indexes (Proc. 26th Annual American Documentation Institute Meeting, Oct. 1963), book, Automation and Scientific Communication, pp. 331–332 (Am. Documentation Inst., 1963).

Youden, W. W., Index to Journal of Association for Computing Machines, ACM J. **10**, No. 4, 583–646 (Oct. 1963).

Yu, H., On the measurement of random chain scission by stress relaxation, Polymer Letters **2**, 631–635 (June 1964).

Zamir, D., Wayne, R. C., Cotts, R. M., On the anomalous NMR linewidth in lithium and sodium, Phys. Rev. Letters **12**, No. 12, 327 (Mar. 23, 1964).

Zapf, T. L., The calibration of inductive voltage dividers and analysis of their operational characteristics, ISA Trans. **2**, No. 3, 195–200 (July 1963).

Zapf, T. L., Chinburg, C. H., Wolf, H. K., Inductive voltage dividers with calculable relative corrections, IEEE Trans. Instr. Meas. **IM–12**, No. 2, 80–85 (Sept. 1963).

Ziegler, B., Wyckoff, J. M., Koch, H. W., Two-crystal scintillation pair-spectrometer, Nuclear Instr. Methods **24**, 301–315 (Feb. 13, 1964).

Zimmerer, R. W., Millimeter wave research at the National Bureau of Standards, Proc. Mountain States Navy Research and Development Clinic, Raton, N.M., Sept. 28–29, 1961, pp. A109–A112 (Raton, Communications and Electronics Foundation, 1963).

Zimmerer, R. W., Spherical mirror Fabry-Perot resonators, Proc. IEEE **II**, No. 5, 371–379 (Sept. 1963).

Zwanzig, R., Elementary derivation of time-correlation formulas for transport coefficients, J. Chem. Phys. **40**, No. 9, 2527–2533 (May 1964).

Zwanzig, R., First order phase transition in a gas of long thin rods, J. Chem. Phys. **39**, No. 7, 1717–1721 (Oct. 1963).

Zwanzig, R., Incoherent inelastic neutron scattering and self-diffusion, Phys. Rev. **133**, No. 1A, A50–A51 (Jan. 1964).

Zwanzig, R., On the identity of three generalized master equations, Physica **30**, 1109–1123 (1964).

Zwanzig, R., Two assumptions in the theory of attractive forces between long saturated chains, J. Chem. Phys. **39**, No. 9, 2251–2258 (Nov. 1963).

Patents

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

Lloyd, Edward C.; Johnson, Daniel P., and Hutton, Ulric O., No. 3,100,912, August 20, 1963. Dual-Wedge High-Pressure Apparatus. (Commerce)

Hefley, Gifford; Linfield, Robert F.; Davis, Thomas L., and Doherty, Robert H., No. 3,106,709, October 8, 1963. Atmospherics Direction Finding System. (Air Force)

Hogue, Ephraim W., No. 3,107,308, October 15, 1963. Transistorized Magnetic Amplifier and Amplifier-Complementer for Digital Computer Circuits. (Air Force)

Pummer, Walter J., and Wall, Leo A., No. 3,109,855, November 5, 1963. Tetrakis-[Pentafluorophenyl]-Silane and Method of Making the Same. (Navy)

Holt, Arthur W., No. 3,112,453, November 26, 1963. Diode Amplifier. (Navy)

Macurdy, Lloyd B., No. 3,112,808, December 3, 1963. Balance Beam. (Commerce)

Ruehrwein, Robert A., No. 3,113,914, December 10, 1963. Process for Making Ozone. (Army)

Stern, Joshua, No. 3,117,491, January 14, 1964. Information Retrieval Apparatus. (Commerce)

Skramstad, Harold K., No. 3,119,928, January 28, 1964. Components for a Combined Digital-Analog Differential Analyzer. (Commerce)

Cleek, Given W., No. 3,119,703, January 28, 1964. Infrared Transmitting Glasses. (Navy)

Hefley, Gifford; Linfield, Robert F.; Doherty, Robert H., and Berger, Earl L., No. 3,122.076, February 25, 1964. Intermittent Action Camera. (Air Force)

Huntoon, Robert D., No. 3,123,821, March 3 1964. Proximity Fuse with Two Oscillators. (Army)

Hermach, Francis L. No. 3,124,747, March 10, 1964. Coaxial Thermal Voltage Converter. (Commerce)

Taylor, John K., and Smith, Stanley W., No. 3,131,348, April 28 1964. Coulometric Titration Coulometer. (Commerce)

Jacobs, Robert B.; Mullen, Lewis O.; Van Gundy, Donald A.; Richards, Robert J. and Steward, Willis G., No. 3,137,143, June 16, 1964. Condensing Vacuum Insulation (Army)

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