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RESEARCH HIGHLIGHTS

OF THE

NATIONAL BUREAU OF STANDARDS

ANNUAL REPORT

1901 NBS 1961

I often say that when you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be.

Lord Kelvin - 1883.

In this sixtieth year of the National Bureau of Standards, Lord Kelvin's perceptive statement must be read in terms of its critical application to every significant area of modern science and technology. Our ability to control or to make use of nature's resources is directly dependent upon our quantitative understanding of the physical world, and on our ability to practice precision measurement. The gaps between basic data and applied research and between research and development are bridged by precision knowledge and advanced measurement processes. Measurement thus serves as the language of science as well as the means for applying research for the advancement of our general welfare. From this, we derive the inescapable conclusion that excellence in the science of physical measurement is an essential foundation for leadership in the progress of science and technology.

A. V. Astin, *Director, NBS.*

UNITED STATES DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*
Hickman Price, Jr., *Assistant Secretary for Domestic Affairs*
NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

1961
Research Highlights
of the
National Bureau of Standards

Annual Report, Fiscal Year 1961

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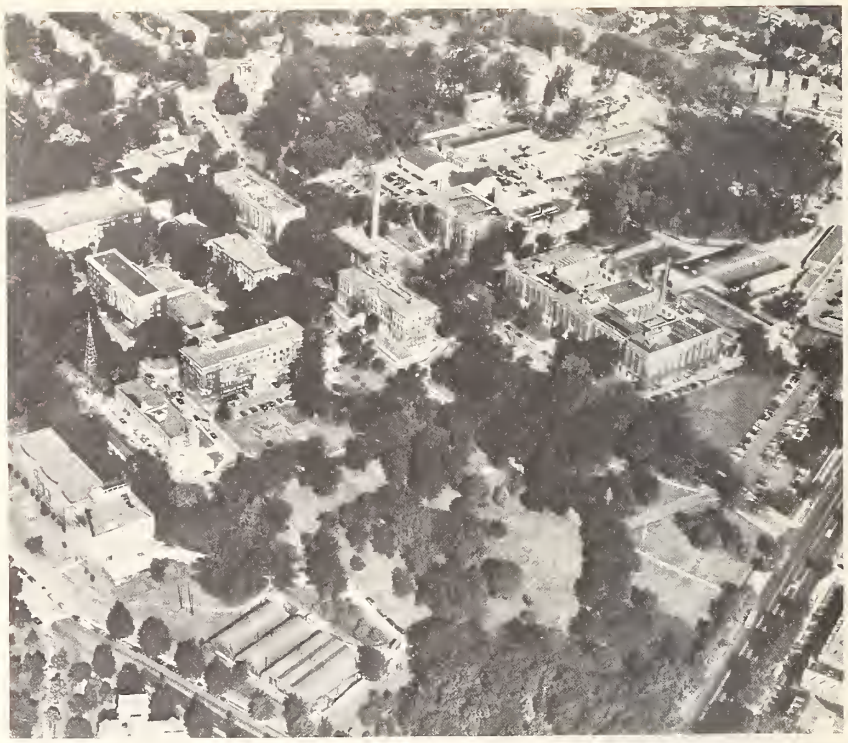


The National Bureau of Standards, Washington, D.C., laboratories (top) and Boulder, Colorado, laboratories (bottom).

Contents

1. GENERAL REVIEW

On March 3, 1961, the National Bureau of Standards completed 60 years of service to science, industry, and commerce. Throughout this period it has been concerned with precision physical measurement, with the promotion of reliable and uniform measurement in the United States, and with a wide variety of research activities.

For measurements to have general meaning and validity, they must be based on common units and standards that are precisely and reliably known. Only then can there be effective interchange of information among scientists, realistic utilization of scientific data by engineers and technologists, orderly exchange of goods in commerce, and realization of the concept of interchangeable parts throughout industry. It is the Bureau's responsibility to develop and maintain the national standards upon which all measurements in this country are based, and to see that these standards are made available to science and industry through suitable calibration services.

A second important responsibility of the Bureau is to provide reliable and precise data on the basic properties of matter and materials that are of importance to science and industry. As such data are obtained by precise measurement, the performance of this function both draws upon and at the same time increases the Bureau's background of knowledge and competence in the field of measurement.

Through a broad program of research in the physical sciences, the Bureau continually strives to keep abreast of the measurement requirements of American science and technology. To insure that measurement inadequacies do not retard progress, it must anticipate tomorrow's measurement problems and lead in their solution, developing new standards and measurement techniques as new fields open up or become more active.

Such a research program provides a broad basis for service to the Government and the Nation in a variety of other ways. These include the development of test methods for materials, cooperation in the establishment of codes and specifications, and advisory services to other Government agencies on technical problems.

A third major NBS responsibility is the operation of central research and technical service programs for the Federal Government. Included in this category are the Central Radio Propagation Laboratory, the Data Processing Systems Laboratory, the Building Research Division, the National Hydraulics Laboratory and the Cryogenic Engineering Laboratory.

This report attempts to present the highlights of the Bureau's program for the fiscal year 1961. In section 2, the body of the report, representative studies and achievements from the various fields in which the Bureau is active

have been selected for brief presentation. However, the breadth of the program and the diversity of projects may make it difficult for the reader to obtain a coherent picture of the year's activity. The remainder of section 1 is therefore devoted to a brief summary of the more important accomplishments and activities of the year.

Progress in Measurement Standards

To provide a basis for accurate electrical measurements, the Bureau maintains very precise standards of electrical resistance and voltage from which all other electrical and electronic standards are derived. The values assigned to these two basic electrical standards are calculated from extremely precise measurements made in terms of the basic units of length, mass, and time. Such measurements, which must be periodically repeated, serve to fix the relation between the electrical and mechanical units so that they may be used together with consistent results.

During the year, the NBS unit of resistance was redetermined by a new, more accurate method. The determination made use of a capacitor whose value can be calculated to a high degree of accuracy from its dimensions. The NBS unit of resistance was then evaluated by comparison with this capacitor. The value obtained was self-consistent to better than a part in a million and was within approximately two parts per million of the value of the ohm as maintained by NBS on the basis of earlier measurement techniques.

A basic problem in electrical standardizing laboratories has been to translate direct-current measurements, which are closely related to the fundamental standards, into alternating-current measurements at the frequencies used in electrical power generation and in radio and electronics work. A recent contribution to the solution of this problem was the development of a "differential thermocouple voltmeter" which indicates directly the percentage difference between an unknown alternating voltage and a previously standardized voltage.

The Bureau's atomic standard of frequency, which is now maintained by means of a natural frequency of the cesium atom, was operated on a regular basis throughout the year and was used to monitor the NBS standard frequency broadcasts. International comparisons showed continued agreement between this standard and the atomic frequency standards of Switzerland and the United Kingdom to 1 or 2 parts in 10 billion. The high stability of atomic frequency standards led to active consideration, on the international level, of specific plans for a redefinition of the second in terms of an atomic frequency.

To disseminate the frequency standard more effectively, the Bureau is working toward the construction of a standard frequency broadcast station to be located near Fort Collins, Colo. The new station will transmit frequencies of 20 and 60 kilocycles. Because these lower frequencies are transmitted directly along the surface of the earth rather than by reflection from the ionosphere, the received signals are much more stable. This permits

their transmission over great distances with greater accuracy than the short-wave broadcasts of NBS stations WWV and WWVH. The new station will have a much higher radiated power than the Bureau's existing low-frequency stations near Boulder, Colo.

Intensive research programs were continued to develop standards and measurement techniques for very high temperatures and pressures. Reliable temperature measurements were made by spectroscopic techniques in the vicinity of 16,000 °C, and extremely compact equipment recently developed for generating pressures in excess of 1 million pounds per square inch was further refined. Pressures reached in an experiment with this equipment can now be predicted within a few percent, as compared with 20 percent a year ago.

In recent years there has been great scientific interest in research at extremely low temperatures, within a few degrees or less of absolute zero. In this temperature region the molecules of which matter is composed become less active in their constant motion, so that much can be learned about the ultimate nature of matter.

As the success of physical research at the low temperatures depends to a great extent upon the accuracy with which temperatures can be measured in this region, the Bureau has been conducting an active program to provide a temperature scale and thermometer calibration service in the range from 1.5 to 20 °K (−457 to −423 °F). In 1961 an acoustical interferometer was constructed and used successfully to measure very low absolute temperatures in the liquid helium range. Further development of this instrument, which makes use of the change in the velocity of sound in helium gas with temperature, is continuing. Favorable results were also obtained in investigations of carbon and germanium resistors for use as precision secondary thermometers in the liquid helium temperature region.

Reliable precision measurement techniques and standards for neutrons are urgently needed both in the power reactor field and in various areas of basic and applied research, such as the study of radiation effects and the development of health physics instrumentation. Although the Bureau has developed a low-intensity neutron standard, it has lacked facilities for measuring the high-intensity fluxes that occur in a nuclear reactor. At the close of the year design work was nearly complete for a high-flux research reactor to be constructed at the Bureau's new site at Gaithersburg, Md. The reactor, to be known as the NBSR, will enable the Bureau to fill its growing responsibilities in the many rapidly expanding fields of atomic energy. The reactor will advance the measurement and understanding of the effects of radiation on substances of all kinds, and will provide a powerful tool for analysis of atomic and molecular structure. Of particular importance among the basic processes to be studied is that of fission. Inadequate understanding of this process still limits the design of fissile material breeding plants.

The value of a uranium reactor fuel depends on the abundance of the uranium-235 isotope and accurate standards of composition are required to make precise mass spectrometric determinations of this abundance. During

the past year, a special mass spectrometer was developed for analyzing uranium hexafluoride; it is being used to evaluate standards having low concentrations of uranium 235. This instrument has also been used to compare the natural abundances of uranium in samples from different geographical areas.

In the past several years, measurements of very low levels of radioactivity have become more numerous and exacting in such fields as archeological dating, biological and medical studies, and health physics. Because of this increased activity, a thorough investigation into the radioactive contamination of materials used in radiation detection has become necessary, and a demand for radioactivity standards at very low concentrations has arisen. To meet this need, a new laboratory facility for the measurement of very low levels of radioactivity—down to a millionth of a curie—was constructed. This facility is being used to study methods of measuring the amounts of radionuclides present at very low concentrations and in making international comparisons of radioactive samples at these concentrations. It will also be used to prepare accurate radionuclide standards for a number of scientific and industrial applications.

Other work on radioactivity standards resulted in the development of a manganese-54 point source standard, a scandium-46 gamma-ray standard, an iron-55 electron-capturing nuclide standard, and a promethium-147 beta-ray standard. In addition, a more accurate value for the half-life of carbon 14—important in geological and archeological dating—was obtained. The new value is 5,760 years with an overall probable error of 1 percent, and is about 4 percent greater than the previously accepted value of 5,568 years.

Measurements of the acidity or basicity of solutions, expressed on the *p*H scale, are of critical importance not only in chemical analysis and medical research but in the control of many industrial processes. Some years ago the Bureau took the lead in establishing a standard *p*H scale that would meet the needs of both science and industry. Standards for the adjustment of *p*H-measuring equipment to conform to this scale have been issued by NBS for more than 15 years. However, fundamental difficulties in the calculation of a standard *p*H have made it necessary to limit the accuracy in the assignment of *p*H values to ± 0.01 unit. Within the past year a mutually satisfactory convention was developed in cooperation with the *p*H committee of the British Standards Institution, and the third decimal place is now being assigned to *p*H standard values.

In response to many requests, a new standard was established especially for the measurement of the *p*H of blood and physiological media. Accurate measurements of the *p*H of blood are of great importance both in medical research and in the diagnosis of pathological conditions. However, the changes in *p*H that must be detected are very small. To increase the accuracy with which these measurements can be made, the new standard was required to have, at body temperature, about the same *p*H as blood. It was prepared from *p*H standard materials already issued by the Bureau.

Studies of Matter and Materials

Water, because of its abundance, its importance to the physical sciences, and its role as a life-supporting liquid, has been the subject of intense study for many years. Recently, by applying an electrophoretic ion-exclusion technique, the Bureau succeeded in preparing water of extremely low ion content. This water has an electrical conductivity of 0.039×10^{-6} ohm^{-1} at 18 °C, indicating a residual ion content which is equivalent to a sodium chloride concentration of one part per billion. Containing less than one-third of the ionic impurities of the water prepared by Kohlrausch and Heydweiller in their historic purification experiments, this water approaches the theoretical conductivity—and ideal purity—more closely than any previously reported.

In 1960 Bureau scientists found that ethane molecules lose molecular hydrogen when subjected to ultraviolet light of very short wavelength. During the past year additional studies were made of the effect of radiation on other simple molecules. Ethylene was found to decompose by a similar process, and further experiments with ethylene showed that molecular detachment of hydrogen also occurs under the action of gamma rays. Such experiments give valuable insight into the detailed processes induced by high-energy radiation and provide information on the origin of radiation damage to materials. The formation of molecular hydrogen by action of ultraviolet radiation on water vapor was also observed; this process may account for the presence of hydrogen molecules in the upper atmosphere.

Detailed investigations of the structures of several important molecules were carried out by spectroscopic studies in the ultraviolet, visible, infrared, and microwave regions of the spectrum. Through the use of microwave techniques, it was possible to measure interatomic distances with very high accuracy in a variety of hydrocarbons and their simple derivatives. Small variations were detected in the lengths of the bonds between carbon atoms in these molecules, and these changes shed some light on the nature of the chemical bonds. The microwave studies also provided other molecular information, such as electric dipole moments and quadrupole coupling constants, which can be correlated with the geometric structure of the molecules.

High magnetic fields have important uses as deflectors of charged particles in the particle accelerators and detection devices of nuclear physics, in nuclear power converters, and for plasma containment in fusion reactors. If the magnet is cooled to low temperatures so as to greatly reduce its electrical resistance, a considerable amount of power that would otherwise be lost as heat becomes available for producing a higher magnetic field. To take advantage of this principle, a high-purity aluminum foil magnet with liquid hydrogen cooling for low-temperature operation was recently designed and is nearing completion. Using only 4 kilowatts of power, it is designed to produce a magnetic field of 100,000 gauss in a cylindrical volume 3 inches in diameter by 8 inches long.

At very low temperatures some metals such as lead and tin become superconductors, that is, they completely lose their electrical resistance. Obviously a superconducting electromagnet would provide a very effective means of obtaining extremely high magnetic fields. Until recently, however, such a superconducting magnet was not regarded as practical because most superconductors are driven into the normal, conducting state by rather small magnetic fields. Within the past year several alloys or compounds have been discovered that remain superconducting in the presence of high magnetic fields and while carrying large currents. One of these, a niobium-tin compound (Nb_3Sn) clad in niobium, has been investigated by the Bureau, with the support of the Atomic Energy Commission, in fields up to 190,000 gauss. The results indicate that this material can be used to make solenoidal magnets that will produce magnetic fields of well over 100,000 gauss if operated from 1 to 4 degrees above absolute zero.

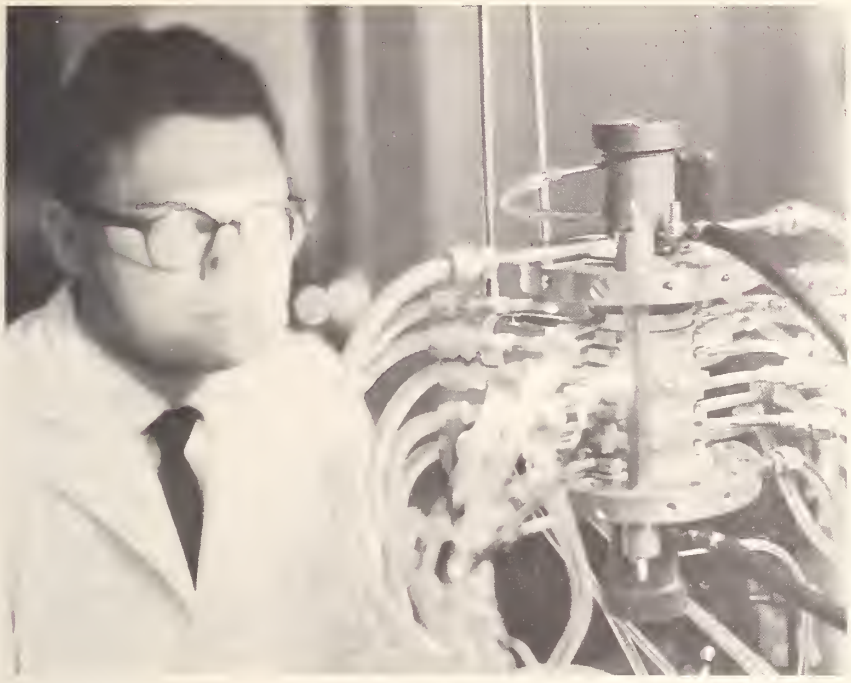
Astrophysical and Plasma Physics Research

In recent years there has been great scientific interest in the nature and physical behavior of extremely hot gases such as occur in thermonuclear devices and in outer space. Yet this field of physics is still very poorly understood. As a result of this lack of knowledge, progress is being held up in a number of important branches of science and technology—among them space exploration and astronomy, thermonuclear power and plasma physics, ultra high temperature research, atmospheric research, and ballistic missile defense systems.

In this situation the major problem is a lack of precise measurement techniques, standards, and basic data on the fundamental properties of the hot gas or plasma. Many of the laboratories attempting to apply plasma physics to practical objectives are thus forced to rely on costly and inefficient empirical methods. To help solve this problem, the Bureau in 1960 began a special effort to unify and strengthen its work in plasma physics and astrophysics. This work is now being carefully coordinated to develop the necessary measurement standards, basic data, theoretical guidance, and interpretative techniques for determining the relevant properties of hot gases and for the solution of important problems in modern astrophysics.

The most immediate need for such knowledge and services arises in the space sciences, where satellites are used to carry equipment outside of the earth's atmosphere to study the sun and the stars. The value of the spectroscopic data thus obtained can be greatly enhanced if they can be accurately described in measurement units based on precise laboratory standards. The Bureau is making accurate measurements of atomic properties to provide the data necessary for quantitative interpretation of these astronomical observations.

To study the probabilities of atomic transitions associated with hydrogen and oxygen lines observed in solar and stellar spectra, the Bureau developed a wall-stabilized high-current arc chamber operating in hydrogen at 12,000



A high-current arc chamber operating in hydrogen at 12,000 °K, a temperature twice that of the sun. The arc is used in research on the fundamental properties of extremely hot gases such as occur in thermonuclear processes and outer space. Lack of precise measurement techniques, standards, and basic data on the fundamental properties of plasmas is a major problem in the space sciences (page 6).

°K, a temperature twice that of the sun. A characteristic red light emitted by the hydrogen through slits in the arc chamber is photoelectrically recorded with a spectrometer and provides information to determine temperature and particle concentrations within the plasma.

A tabulation of the relative intensities of 39,000 spectral lines was completed during the year, providing intensity values on a uniform energy scale for 70 elements over the wavelength range from 2000 to 9000 Angstrom units. The new tables will supply much-needed quantitative intensity values for those elements most commonly encountered in spectrochemical analysis. The intensity values may be transformed into atomic transition probabilities and used to determine temperatures of laboratory light sources emitting atomic spectra and of stellar atmospheres.

In addition to the data center on atomic transition probabilities which was set up last year, a data center on atomic collision cross sections was established to gather and index all published information in this field. A complete file of scientific papers on low-energy electron cross sections has been collected, and about one-half of the papers have been coded on punched cards. Plans call for extending the data collection to other atomic cross sections as soon as is feasible.

Through the production of radio waves from plasmas in the laboratory, a major step was taken toward duplicating under controlled conditions the electromagnetic processes which occur in the upper atmosphere. Plasmas were produced in helium by a high-velocity shockwave travelling over 100 times the speed of sound. When the plasmas were studied in the presence of a transverse magnetic field, radio waves resulting from interaction between the shockwave and the magnetic field were observed. A high-speed camera, capable of operating at over 100 million frames per second, was devised to study the luminous phenomena in the shockwaves.

Radio Propagation Research

The NBS Central Radio Propagation Laboratory (CRPL) has the primary responsibility within the Federal Government for collecting and disseminating information on radio wave propagation. The results of its research program are of value to radio and television broadcasters, the military services, space scientists, and operators of many types of communication systems.

A large part of CRPL research deals with the properties of the series of electrically charged layers in the upper atmosphere known collectively as the ionosphere. Through their ability to reflect radio waves, these layers play an important part in long-distance radio communication.

By analyzing radio signals received from satellites, CRPL has been able to study the structure of the upper part of the ionosphere, measuring the density of electrons and other characteristics. Current studies are investigating the size, shape, and motion of various ionospheric irregularities as observed at a number of stations. The results obtained in this work should aid communication with space vehicles since radio signals from space are seriously affected by irregularities in the electron density of the ionosphere.

On June 24, 1961 the first rocket-borne soundings of the topside of the ionosphere were made by means of a four-stage rocket carried to an altitude of over 600 miles. Successful radio pulse reflections from the topside of the ionosphere were obtained for about 13 of the 14 minutes that the payload was above the ionosphere.

The rocket, a Javelin, was launched from the National Aeronautics and Space Administration's Wallops Island (Va.) facility. The purpose of the experiment was to test the sounding system that is to be used in a topside sounding satellite to be placed in orbit at a later date. Such a satellite will be of great value in advancing man's knowledge of the ionosphere. NBS responsibilities in this program include overall planning, design and performance of the experiment, and analysis of the resulting data. Airborne Instruments Laboratory, a division of Cutler-Hammer, Inc., is designing and building the rocket and satellite payloads and the ground data-handling equipment. Technical management and sponsorship is by the NASA Goddard Space Flight Center.

Data Processing Systems

The Bureau continued to serve the Government as a central research and development agency in automatic data processing and as a readily available information center for the solution of specific problems in this field. During 1961 services to other Federal agencies included assistance to the Bureau of Naval Weapons on problems of weapons-systems evaluation and test-range instrumentation of the Pacific Missile Range; studies of a future air-traffic control system for the Federation Aviation Agency; research for the Navy on computer methods for translating aerial photographic information into elevation profiles; and development of a program for simulating municipal traffic flow by high-speed automatic data-processing equipment for the Bureau of Public Roads.

In studies of computer components, significant advances were made in the theoretical analysis of solid-state semiconductor devices operating as circuit elements. For example, a large-signal equivalent circuit, valid for all modes of circuit operation, was produced for junction transistors. Equations were developed that make possible the analytic solution of modes of junction-transistor operation previously considered untractable.

Calibration, Testing, and Standard Samples

The Bureau continued to be faced with the demands of a rapidly expanding technology for calibration services to insure accuracy in laboratory, shop, and plant, and to meet the need of state and local weights and measures enforcement officers. In meeting these critical needs it was aided by the extensive calibration programs that are being established in the military agencies and in many industries and private standards laboratories. The Bureau continued, insofar as possible, to restrict its calibration work to master standards and high-precision instruments, leaving the calibration of lower-echelon standards to the other standards laboratories that have been set up. To an increasing extent, the Bureau was called upon for assistance to these laboratories.

The activity of the Aerospace Industries Association, in surveying the measurement needs of its member firms, has proved very useful and informative to the Bureau in planning and developing calibration services. In 1959, the Association questioned 70 companies in its field and found greatly increased measurement needs in several critical areas such as microwave, temperature, vibration, and shock measurements. Over 100 of these needs were for measurement and calibration services not then offered by NBS. Either the Bureau did not provide any service for the particular physical quantity involved, or the range of measurement or accuracy required was not available. This survey clearly showed the immediate need for more basic research on measurement problems and increased industry-wide dissemination of calibration procedures.

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As a followup to the AIA Industry Calibration Survey, a series of 16 meetings between measurement specialists from AIA member firms and NBS technical staff members was held at the Bureau over the past 14 months. Aimed at bringing into sharp focus the impact of the "measurement pinch" as it affects the aeronautical and missile industries, these conferences dealt with the following subjects: Temperature; infrared radiation; humidity; vacuum and flow; force and acceleration; shock and vibration; internal diameters; surface flatness and finish; gear calibration and measurement; pulsed voltage; radiofrequency impedance and phase; radiofrequency power, current, and impedance; radiofrequency voltage and field strength; microwave power; microwave attenuation; microwave VSWR, impedance, and phase. The conferences identified many specific areas in which the aircraft and space industries face severe measurement problems. For example, an industry representative cited a million-dollar development of radomes which had to proceed more by trial and error than by test and analysis, because precise phase and amplitude measurement capabilities do not exist in the required frequency range. As a result of the meetings, the Bureau's planning in all the measurement areas that were covered has benefited, and steps have been taken to immediately place greater emphasis on calibrations and related work in the most critical areas such as microwave power and attenuation, high temperature, infrared radiation, and engineering metrology.

To facilitate liaison with those who use the Bureau's services, a new Technical Advisory Committee on Calibration and Measurement Services was established. The committee includes leaders in specialized fields drawn from industry, and will foster NBS-industry cooperation in precision measurement. It will advise the Bureau concerning current and anticipated needs of industry for measurement and calibration services, indicating the extent and relative urgency of these needs and suggesting how the Bureau's skills and resources may best be utilized toward meeting them.

The Bureau has also been working closely with the Department of Defense and its contractors to keep informed of new measurement problems and calibration needs. During 1961 a series of visits to the plants of Air Force contractors was made by a Joint NBS-U.S. Air Force Working Group on Standards. It was found that significant progress has been made in measurement standards activities over the past few years and in most plants a keen awareness of the need for highly accurate standards of physical measurement has developed. At the suggestion of several defense agencies, the Bureau's Electronic Calibration Center held a 5-day workshop on microwave frequency measurements for technical supervisors from standards laboratories in the Department of Defense.

The greatly increased activity in measurement standards throughout the country was indicated by proposals from various sources for the establishment of associations to deal with technical and administrative problems of the industrial standards laboratories that are being set up to serve as intermediaries in the calibration chain between NBS and industrial plants.

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, resistance, reactance, and capacitance standards, d-c to 30 kc.	8,927	$146,780.46	2,096	$41,480.25	11,023	$188,260.71
Metrology	Light and color standards, photographic lenses, gage blocks and other length standards, refractive index standards, sieves, mass standards, track scales, capacity standards.	41,079	235,148.40	4,993	83,470.36	46,072	318,618.76
Heat	Resistance and liquid-in-glass thermometers, thermocouples, pyrometers.	6,965	121,906.31	1,724	36,776.00	8,689	158,682.31
Radiation Physics	Neutron sources and instruments, X-ray and gamma-ray protective materials and instruments, gamma-ray sources, alpha-ray sources, radioactive materials.	206	8,277.00	384	11,463.00	590	19,740.00
Mechanics	Acoustic instruments, proving rings, load cells, dynamometers, pressure standards, water current meters.	4,293	163,182.84	1,519	51,709.48	5,812	214,892.32
Radio Standards	Electrical and electronic instruments and standards in radio, ultra-high frequency and microwave ranges.	1,818	103,053.91	2,797	861,890.28	4,615	964,944.19
Building Research	Thermal conductivity	26	2,760.00	5	2,775.00	31	5,535.00
Totals		63,314	781,108.92	13,518	1,089,564.37	76,832	1,870,673.29

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			501	$6,439.00	501	$6,439.00
Metrology	Lamps			4,482	52,000.00	4,482	52,000.00
Analytical and Inorganic Chemistry.	Chemical analysis	11	$1,185.00	61	1,836.00	72	3,021.00
Mechanics	Mechanical devices			1,699	15,068.50	1,699	15,068.50
Organic and Fibrous Materials.	Paper, textiles, rubber, leather and plastic products	67	2,185.25	5,549	131,225.50	5,616	133,410.75
Metallurgy	Metals and alloys			41	20,016.00	41	20,016.00
Mineral Products	Ceramic products, glass	1	57.00	16	2,400.00	17	2,457.00
Building Research	Building materials, elevators, air filters, fire extinguishers, heating and air conditioning equipment, paints and other surface coatings.	38	15,039.00	1,151	51,516.68	1,189	66,555.68
	Cement	1,226	47,217.73	22,548	854,151.85	23,774	901,369.58
	Concrete and concreting materials	14	608.01	15,303	156,666.25	15,317	157,274.26
Totals		1,357	66,291.99	51,351	1,291,319.78	52,708	1,357,611.77

TABLE 3. *Standard samples issued*

Area of Bureau activities	Description of samples	Public		Government		Total	
		Number of samples	Value	Number of samples	Value	Number of samples	Value
Metrology	Resolution test charts	9,276	$1,855.20	1,242	$248.40	10,518	$2,103.60
	Calibrated glass spheres	117	1,111.50	11	104.50	128	1,216.00
	Photometric standards	306	11,761.00	40	1,685.00	346	13,446.00
	Spectrophotometric standards	81	6,650.00	8	571.00	89	7,221.90
	Color temperature standards	44	2,382.00	11	350.00	55	2,732.00
	Reflectance standards	151	2,520.00	35	462.00	186	2,982.00
	Opacity standards	134	3,521.00	5	106.00	139	3,627.00
	Gloss standards	236	3,435.00	16	198.90	252	3,633.00
	Signal glass limit standards	102	6,582.00			102	6,582.00
	Haze standards	128	1,781.00			128	1,781.00
	Radiance standards	29	8,120.00	12	3,360.00	41	11,480.00
Atomic and Radiation Physics	Radiation lamps	26	2,054.00	15	1,185.00	41	3,239.00
	Radioactive samples	289	8,355.00	233	6,523.50	522	14,878.50
Chemistry	Standard benzoic acid thermometric cells	4	880.00			4	880.00
	Other thermometric cells	21	1,050.00			21	1,050.00
	Pure hydrocarbons	765	23,514.00	146	4,219.00	911	27,733.00
	Hydrocarbon blends	194	2,328.00			194	2,328.09
	Spectrographic standards	4,181	52,723.00	366	4,496.00	4,547	57,219.00
	Pure substances, metals, alloys, ores	19,875	88,211.50	1,412	5,933.55	21,287	94,145.05
	Uranium isotopic standards	626	8,198.50	73	1,031.50	699	9,230.00
	Cylinders of certified natural gas	99	7,425.00			99	7,425.00
	Labeled carbohydrates	16,042	13,337.00	6,945	2,205.00	22,987	15,542.00
	Metal-organic material	1,783	10,698.00	187	1,122.00	1,970	11,820.00
	Sucrose and dextrose	244	915.00	69	258.75	313	1,173.75
Mechanics	Viscosity oils	872	15,052.00	99	1,502.00	971	16,554 00
Organic and Fibrous Materials	Standard fading samples	526	6,203.00	18	128.00	544	6,331.00
	Rubber and compounding ingredients	6,386	40,772.40	30	156.00	6,416	40,928.40
	Phosphor reference samples	42	126.00	8	24.00	50	150.00
Metallurgy	Standard thickness samples for electroplated coatings	1,674	17,022.50			1,674	17,022.50
	Gases-in-metals samples	191	1,910.00	11	110.00	202	2,020.00
Building Research	Limestone slabs	7	175.00	8	200.00	15	375.00
	Surface flammability standards	35	280.00			35	280.00
	Paint pigments	21	63.00	11	33.00	32	96.00
	Cement standard samples	2,475	6,187.50	155	387.50	2,630	6,575.00
Total		66,982	357,199.10	11,166	36,599.70	78,148	393,798.80

During the year the Bureau participated in several meetings initiated by representatives of industrial standards laboratories to determine the need for and possible role of an association of standards laboratories.

A three-volume Handbook entitled *Precision Measurement and Calibration* was issued to provide a "textbook" and reference source for the many scientists and engineers who must be trained in the shortest possible time to fill responsible positions within the new standards laboratories. This 2800-page Handbook is a compilation of technical papers on measurement and calibration by the NBS staff. The three volumes, extensive as they are, include only a fraction of the Bureau's work relating to measurement; however, supplementary references are listed and many of the reprinted papers include bibliographies in this field.

An important medium for the exchange of information on electronic measurements was the Conference on Standards and Electronic Measurements, during the summer of 1960, at the Boulder Laboratories. Sponsored jointly by the American Institute of Electrical Engineers, the Institute of Radio Engineers, and NBS, the three-day meeting was attended by more than 800 scientists and engineers from industry, universities, and Government. The Bureau also cooperated with the American Institute of Physics and the Instrument Society of America in sponsoring a Symposium on Temperature—Its Measurement and Control in Science and Industry, held in Columbus, Ohio, March 27–31. More than 250 papers were presented at this Symposium, the fourth in a series begun in 1919.

The nature and scope of the activity in calibration and testing are shown for fiscal year 1961 in tables 1 and 2. A total of 129,540 calibrations and tests were performed for Government and industry.

Closely related to the calibration effort is the standard materials program (table 3). During the past year the Bureau distributed 78,148 samples of standard materials to other laboratories for use in controlling chemical processes and in maintaining the accuracy of apparatus and equipment. Over 600 different standard materials are at present available—principally chemicals, ceramics, metals, ores, and radioactive nuclides. All are certified either for chemical composition or with respect to a specific physical or chemical property such as melting point, viscosity, color, or index of refraction.

Cooperative Activities

The Bureau cooperates extensively with Federal, State, and local governments; with national professional societies and standardizing bodies; and with many international groups. In this way the results of Bureau research are brought to bear on many current problems of science and industry, particularly those relating to measurement standards, building and safety codes, engineering and purchase specifications, and test methods.

Cooperation with other Federal agencies ranges from the supplying of technical information upon request to long-range projects undertaken through

various scientific and technical committees. An important example of interagency cooperation is the development of Government specifications and test methods. During the year at the request of the General Services Administration, the Bureau accepted responsibility for developing and maintaining 7 additional Federal Specifications, making a total of 157 for which it now has this responsibility. The Bureau also reviewed approximately 400 proposed specifications both for GSA and for other agencies to determine their suitability for use by the Federal Government.

Cooperation with State and municipal governments is principally in the field of weights and measures. Although the Bureau itself does not have regulatory powers, it offers technical advice and consultation to local regulatory bodies and it calibrates and adjusts State standards of weights and measures. A major medium of cooperation is the National Conference on Weights and Measures. Thirty-five States, the District of Columbia, Puerto Rico, Canada, and the United Kingdom were officially represented at the 46th annual meeting of this Conference, held in Washington, D.C., June 12–16, under NBS sponsorship.

Through the participation of Bureau staff members in the work of national professional societies and standardizing bodies, the Bureau plays an active role in the development of test methods and criteria, in the application of scientific discoveries, and in fundamental research programs of national scope. During the past year Bureau staff members held 1,250 committee memberships in 150 national groups such as the American Society for Testing Materials, the American Standards Association, American Society of Mechanical Engineers, American Chemical Society, Institute of Radio Engineers, and Instrument Society of America.

In many of these groups NBS staff members work with industry to provide codes and specifications, standard test methods, and standard data on the properties of engineering materials. To help the Bureau cooperate with industry in these areas, a new Technical Advisory Committee on Engineering and Related Standards was established. This Committee will be concerned with national needs in the general field of standard practices and will seek to maintain awareness of the efforts of private organizations in this field, fostering cooperative programs and recommending use of the Bureau's special competence where needed.

Other means of Bureau-industry cooperation include 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 11 groups are supporting research associates at the Bureau (appendix, p. 175).

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, eight projects were supported by gifts from six organizations (p. 175).

On an international basis, the Bureau represents the interest of the Government and American science in matters dealing with the establishment and maintenance of standards and establishment of values for scientific constants. Most of this work is done through participation in a large number of international groups such as the International Union of Pure and Applied Chemistry, International Scientific Radio Union, International Commission on Illumination, and International Organization for Standardization. Approximately 124 staff members attended meetings of international societies during the fiscal year.

In October 1960 the Director of the National Bureau of Standards and the Chief of the NBS Metrology Division attended the 11th General Conference on Weights and Measures, in Paris, as head and member, respectively, of the American delegation. An outstanding accomplishment of this Conference was the adoption of a new international standard of length—a wavelength of light—replacing the meter bar which had served as the standard for over 70 years. The meter was thus defined as 1,650,763.73 wavelengths of the orange-red line of the isotope krypton 86. Other actions taken by the Conference included the establishment of a central facility at the International Bureau of Weights and Measures for international coordination of radiation measurements, confirmation of a new definition of the second of time in terms of the tropical year 1900, and adoption of refinements in the scales for temperature measurements.

In April 1961 the National Bureau of Standards was represented at the Pan American Standards Committee Meeting in Montevideo, Uruguay, by an Associate Director and a Consultant to the Director. These staff members also visited several other South American countries to confer with representatives of Government and industry regarding the development and promotion of standards for Latin American raw materials and semi-manufactured products, to discuss exchange of personnel between NBS and Latin American standards laboratories, and to inquire into the effect on commerce and trade of the disparity between the English units of measurement used in the United States and the metric system employed in Latin American countries.

Another aspect of international cooperation involves a program whereby scientists or diplomatic representatives from other countries are accepted at the Bureau as guest workers or visitors. Approximately 1,100 foreign scientists and technicians, representing 61 countries, visited the Bureau during the year. Forty-five of these visitors were specialists who came as guest workers to spend from 1 to 12 months in cooperative research. Twenty were trainees who were being prepared for leadership in the national laboratories of their own countries.

Administrative Activities

A number of administrative changes were made as part of the Bureau's efforts to meet the expanding needs of modern science and technology. The divisional reorganization which began in 1960 was completed in 1961 with the subdivision of the former Chemistry Division into two more cohesive divisions: Analytical and Inorganic Chemistry, and Physical Chemistry. In another change, the technical Associate Directors were relieved of responsibility for supervision of particular divisions so that they could spend full time in staff work for the Director and Deputy Director. (See appendix, p. 159, for revised organization.) Also, advisory committees of outside experts were set up in the areas of calibration and measurement services (p. 171), and engineering and related standards (p. 171).

In addition to the existing technical advisory panels appointed by the National Academy of Sciences-National Research Council (appendix 3.4), a special NAS–NRC study was initiated on the Bureau's building research program. The study implements a recommendation of the 1960 report to the Secretary of Commerce by NAS–NRC on the role of the Department in science and technology.

On June 14, Secretary of Commerce Luther H. Hodges broke ground for a new Engineering Mechanics Laboratory. This laboratory is included, along with the power plant and initial site development work, in the first construction contract let for the Bureau's new research center at Gaithersburg, Md. At the Boulder Laboratories construction of a sixth wing for the main laboratory building was well under way.

At the end of the year, the total staff was about 3,900 persons, slightly less than one-third of them at the Boulder Laboratories. Appendix 3.2 gives further data on staffing.

Two new types of positions were established during the year: Senior Research Fellow and Senior Visiting Scientist. Their purpose is to afford recognition to distinguished scientists and to enable them to do independent research and consultation of a broad character beyond the scope of a particular division.

Funds obligated during the year totaled $52,244,000 including $13,406,000 for facilities. Of the $32,812,000 total for the research and development effort, $19,578,000 came from the direct appropriation for Research and Technical Services and $13,234,000 from other agencies and private sources. In addition, calibration, testing, and other services totaled $6,026,000. A more complete presentation of financial data is contained in appendix 3.3.

One of the groups interested in the Bureau's future capabilities is the House Committee on Space and Astronautics. After hearings with Bureau officials, the Committee published a report (House Report No. 711, 87th Congress, 1st Session) which included the following:

"The Bureau of Standards provides a number of services to industry and commerce, to the scientific community generally, and to Federal agencies. . . . its range of interest has, perhaps, a wider scope than that of any other Federal research institution.

"The programs of the Bureau are a large contribution to the work of scientists and engineers of the country. They provide a technical foundation for space, military, and atomic energy programs. Technology and research and development in technological fields play an ever increasingly important part in the life of today. Dr. A. V. Astin, Director of the National Bureau of Standards, sums up this situation as follows:

> 'By almost any measure, the growth of science and technology in this century has been phenomenal. Regardless of whether we look at the rapidly increasing number of scientists, the greatly increased amounts of funds applied to research and development, the staggering growth in the volume of technical literature, or the tremendous multiplication of new devices and materials from our industrial machines, we find a rate of expansion very much in excess of the rate at which the general population is increasing.
>
> 'For some time the rate of growth of the U.S. population has been doubling about every 50 years whereas the number of scientists in several of the major disciplines has been doubling about every 10 years. Comparable exponential growth rates are found with other indices of scientific progress.' "

In light of the growth picture, efforts were continued and extended to determine present and future needs for standards of measurement and associated calibration services. Within the Bureau a more systematic procedure was adopted for evaluation of current programs. Also, program planning began to be projected further into the future as part of the Government-wide effort to develop tentative budget estimates for at least five years in advance.

Publications

Publications are a major end product of the Bureau's research effort. They are the principal means by which the results of NBS projects are made available to science and technology. The publications of the Bureau are therefore suggestive of the scope and level of its technical program. During the year these totaled 937 formally published papers and documents. In addition some 390 classified and unclassified reports were issued to other Government agencies.

A major publication of the year was *Precision Measurement and Calibration* (Handbook 77). This three volume Handbook (p. 14) is a compilation of the more important NBS publications of recent years dealing with precision measurement and the calibration of standards.

Another three-volume reference work was completed with the publication of part III of *Screw Thread Standards for Federal Services* (Handbook 28). This Handbook represents the work of the Interdepartmental Screw Thread Committee, which is sponsored by the Departments of Defense, Army, Navy, Air Force, and Commerce to promote uniformity in screw-thread standards in the Departments concerned.

Other significant reference works were *X-ray Protection Up to Three Million Volts* (Handbook 76), which gives National Committee on Radiation Protection and Measurements recommended safety standards in this field; and *Bibliography of Temperature Measurement* (Monograph 27) which contains more than 500 references published between January 1953 and June 1960 in the field of temperature measurement.

Secretary of Commerce Luther H. Hodges formally breaks ground for the construction of the new NBS laboratories at Gaithersburg, Maryland. The Bureau expects to be relocated in its new campus by 1964. On the speakers' platform behind the Secretary are Dr. A. V. Astin (left), NBS Director, and John L. Moore, Administrator of the General Services Administration (page 17).

Unique among the year's publications was *The Metric System of Measurement* (Miscellaneous Publication 232), a 46- by 29-inch wall chart for classroom use. An updated version of an all-time favorite visual aid, this new metric chart includes the recent redefinition of the meter in terms of a wavelength of light. The chart shows the interrelationships among the units of the International Metric System of measurement, and the relationships between the metric units and the units of the English system.

Of the 937 formal publications issued during the year, 188 were published in the *Journal of Research,* and 573 in the journals of professional and scientific societies. Also, 106 summary articles were presented in the Bureau's monthly *Technical News Bulletin.* Seventy papers were published in the nonperiodical series of publications: 14 in the Monograph series, 8 in the Handbook series, 2 in the Circular series, 8 in the Miscellaneous Publication series, and 38 in the Technical Note series.

Basic Radio Propagation Predictions, the Bureau's third periodical, which is published for a 1-month period 3 months in advance, presented radio propagation data needed for determining the best radiofrequencies to use in long-range radio communications.

A list of publications for the fiscal year is given in the appendix, section 3.8 (p. 176).

During the year, the Bureau participated in 21 scientific and technological exhibitions, with exhibits depicting the Bureau's research programs. Typical of the year's shows were the Instrumentation-Automation Exhibit of the Instrument Society of America, the Northeastern States Exposition of Industrial Progress, and the National Academy of Sciences Annual Exhibit.

The Bureau's motion picture program included 3,111 showings of NBS films to a total audience of 261,493, including educational television.

2. HIGHLIGHTS OF THE RESEARCH PROGRAM

The Bureau's technical program is carried out through organizational units called divisions. These are shown in appendix 4.1 in numerical order. A review of selected research and development programs is presented in this section under headings corresponding generally to these organizational units but rearranged to bring together related types of activity.

2.1. PHYSICS, ELECTRONICS, AND MEASUREMENT STANDARDS

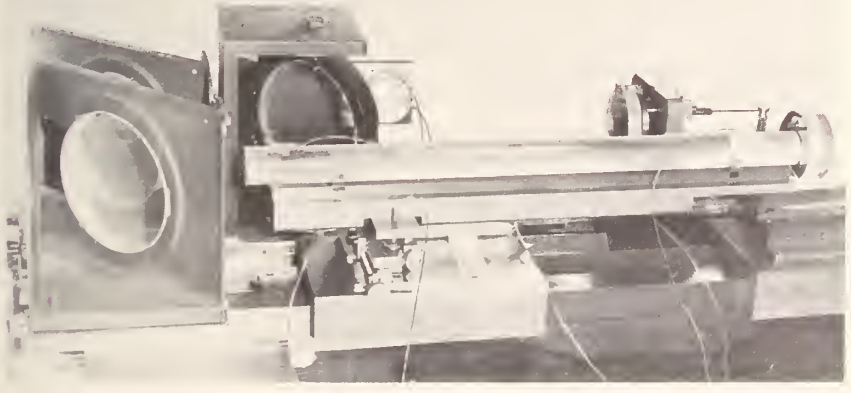
2.1.1. METROLOGY

The metrology laboratories of the Bureau maintain, develop, and disseminate standards for commonly used physical quantities, such as length, mass, volume, density, angle, light, color, refractive index, and other optical and photographic parameters. Included in work of the past year was the development of interferometric methods for measuring both the surface finish and sphericity of ball bearings, a need arising from space-age require-

ments. New single-pan two knife-edge balances, constructed in accord with Bureau specifications, were tested and found suitable for rapid high-precision weighing. The refractive index of specimens of calcium fluoride was measured over a 50-fold range of wavelengths, bracketing the visible spectrum. Progress was achieved in the re-evaluation of physical constants, such as electronic charge, electronic mass, and Avogadro's number, through the use of newly developed experimental data. During the year over 50,000 individual standards were calibrated for scientific and industrial use throughout the country. Thus the metrology laboratories carry out one of the Bureau's basic functions—to provide the means for accurate measurements consistent with the national standards.

Wavelength Standard of Length. Direct measurements of the length of the standard meter bar in terms of the krypton wavelength, prior to its adoption as an international standard. verified that the new standard would not alter effectively the unit of length which had been internationally maintained for over 70 years. At the time of the adoption of this wavelength standard for length by the General Conference on Weights and Measures on October 14, 1960, only one other laboratory besides the Bureau had measured a meter bar directly in terms of the krypton wavelength.

In this work, determinations were made of the number of wavelengths of the orange-red radiation of krypton 86 (6054 A) in a meter. The measurements were made by comparing 50- and 100-cm quartz standards and a 100-cm steel standard with the national prototype meter bar and then determining the number of wavelengths of the orange radiation in these lengths. The average of a series of observations on the two quartz standards and the steel standard gave the number of wavelengths in a meter as 1,650,-764.13 as compared with 1,650,763.73, the value which was adopted. How-



Apparatus used in studies of the relationship between the Krypton-86 wavelength and the meter as defined prior to the adoption of the wavelength standard. Shown is the special Michelson interferometer setup with 50-cm quartz end standard which has been compared with the National Prototype Meter Bar (page 21).

ever, measurements on the steel standard, believed to be the most trustworthy, gave 1,650,763.88 as the number of wavelengths.

A similar series of measurements on a number of different standards at the National Research Council in Canada agreed closely with the Bureau average, although one measurement on a Bureau meter bar by the National Research Council—in which Bureau personnel participated—gave 1,650,763.90 as the number of wavelengths. Bureau representatives and others at the General Conference agreed to adopt 1,650,763.73 wavelengths, since this had the effect of defining the Angstrom unit as exactly 10^{-10} meter.

The interferometric measurements were made with a large Michelson interferometer, which is enclosed in an insulated, airtight chamber with remote controls for positioning the standards and optical elements. Remote measurements of temperature at eleven stations throughout the chamber, and of relative humidity and pressure, can also be made. The chamber is so well insulated that the variation in temperature along the length of a one-meter standard does not exceed 0.003 °C; it can be filled with air of known analysis and the pressure maintained to 0.01 millibar.

Frustrated Total Reflection. Frustrated total reflection involves the effect of a second surface on the complex energy existing on the dark side of a first surface that totally reflects incident light. This phenomenon was used to measure the film thickness existing between a glass-metal interface. The technique, which has a theoretical sensitivity of 20-billionths of an inch, was also employed to determine the proximity of a spherical surface to a plane. The errors in gage-block calibration which may arise from wringing-film thickness will also be investigated by this technique.

Mass Standards. A study was initiated to increase the accuracy of mass measurement that is conveniently attainable through use of bulk buoyancy computations of the air buoyancy. This measurement is now limited to about 3 parts in 10^6 because of uncertainties associated with cavities closed by screw knobs. Tests were started on weights of a new design which retain the advantages of two-piece construction and provide the higher precision and increased constancy now provided by one-piece design.

Weighing Techniques. Four experimental balances were completed. The first two, of 6- and 50-pound capacities, are intended for use in state laboratories where increased precision and speed of operation are required (see p. 157). The third is a novel-type quartz microbalance of 2-gram capacity and the fourth is a 1-kilogram balance of advanced design which will be used in experiments where the maximum attainable level of precision is demanded. The first three were developed jointly with American industry and the fourth was constructed at the Bureau.

Apparatus developed for use in knife-edge research included devices for the measurement of knife-edge radii, friction, erosion, and the effect of electric current through the knife-flat combination. Lathe techniques were devised for achieving 3- to 4-microinch finishes on experimental weights without lapping or polishing. Materials used included aluminum, titanium,

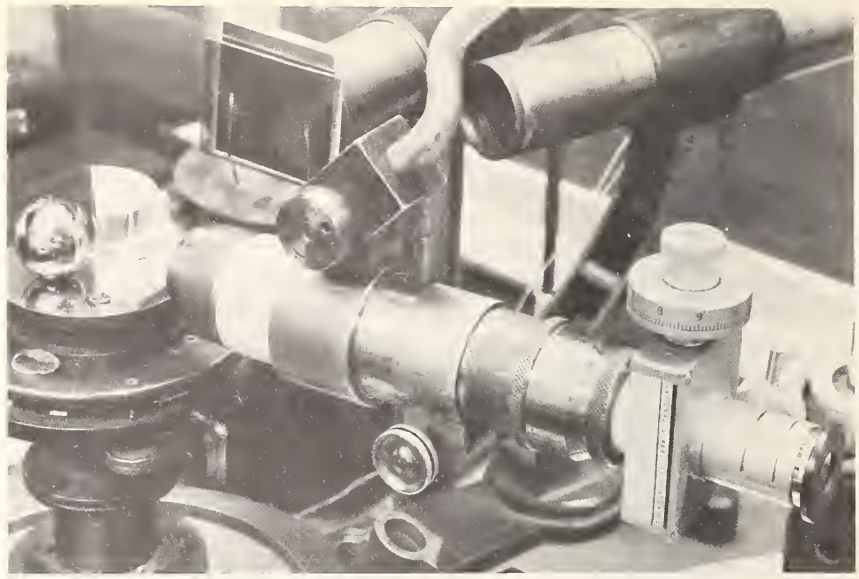
tantalum, brass, tungsten, stainless steel, and a nickel-chromium alloy. Balance component development included an arrestment with no moving parts and a suspension assuring minimum swinging.

Ultraviolet Wavelength Standard Developed. Glasses whose absportion spectra exhibit sharp maxima or minima have long been used to calibrate the wavelength scale of recording spectrophotometers within the wavelength range of 380 to 1080 millimicrons, but none has been available in the ultraviolet range from 240 to 380 mμ. Hence a study was made, in cooperation with a glass manufacturer, to provide a holmium-oxide glass for use in this range. The standard glass developed has five sharp absorption bands between 240 and 380 mμ sufficiently symmetrical that the wavelength of maximum absorptance indicated by the recorder remains constant for slit-widths up to 2 mμ. The standard also shows other bands between 380 and 650 mμ that are useful to supplement other standards used for this range. The new glass, with certified values of the wavelengths of 11 absorption maxima now being issued, makes possible a wavelength calibration accurate to 0.1 mμ.

Filters Selected for Checking Color Measurement Equipment. A recent advance in routine color measurement has been the development of automatic computers, either digital or analog, that can be attached to an automatic spectrophotometer to yield by routine measurement the tristimulus values specifying a particular color. About one hundred such systems are now in operation in American industry, and the current rate of increase is about fifty per year. To provide a means for checking the performance of such systems, the Bureau selected glass filters of five spectral types, and determined the tristimulus values of 100 specimens of each type. If any given spectrophotometer-integrator system yields the certified tristimulus values for all five filters within satisfactory tolerances, it may be concluded that the system is properly designed and adjusted. Furthermore, from the pattern of any significant differences, definite clues are yielded as to the type of malfunction (wavelength-scale, photometric-scale, stray-energy, slit-width) affecting the system.

Irradiance Meters Calibrated. Cooperative work was undertaken with the National Academy of Sciences-National Research Council and the Department of Health, Education, and Welfare, in their study of the effect of ultraviolet radiant energy in reducing the rate of staphylococcus infection in hospitals. Several meters for measuring irradiance of 2537 A flux were calibrated and one of the meters, used as a control meter, was checked periodically during the year.

Color Names Standardized. Progress was made, in a program initiated with the Inter-Society Color Council, to establish and promote the use of a system of simple, precisely defined, color designations. In this study, a set of paint chips was prepared showing the most representative, or centroid, colors for 214 of 267 ISCC–NBS color designations. Arrangements were completed for the mass production of sets of these color standards, mounted on charts for convenient use.



Frustrated total reflection of light was investigated through the interaction of a steel ball and a plane glass surface. The technique has a theoretical sensitivity of 20 billionths of an inch, and may provide an improved method for measuring wringing-film thickness in gage block calibration (page 22).

The resulting charts will be suited for a variety of scientific and industrial uses. For example, they will serve for approximate color specification wherever the ISCC–NBS color designations are applicable, namely, in descriptions of drugs and chemicals, in qualitative chemical analysis, in dermatology, and in descriptions of mica, building materials, soils, and rocks. They will also form the basis for statistical studies of trends in industrial color usage, and they may be useful in planning lines of merchandise having coordinated colors.

Artificial Daylight Standard. Since 1931 the standard artificial daylight for color measurements in the laboratory has been based by international agreement on two-cell, liquid filters developed at the Bureau. During the past year a cooperative study was carried out with Corning Glass Works in which a three-component glass filter was developed for converting incandescent-lamp light into a closer duplication of the spectral character of natural daylight than has previously been possible. These filters may form the basis of a new international agreement on standard sources for colorimetry. In the meantime they can be used as superior color-temperature-altering filters by science and industry.

Color-Rendering Index Developed. The widespread acceptance of fluorescent lamps of high luminous efficacy poses the problem of how closely object colors are rendered in their natural colors by these sources. Since 1952 joint effort has been made with the Illuminating Engineering Society to solve this problem. During the year a tentative method for specifying a color-rendering index was developed and validated for use when the chro-

maticity of the light source to be tested is closely identical to that of the standard against which it is to be compared.

This tentative method has been accepted by the Committee on Color Rendition of the International Commission on Illumination as one of two closely similar methods on which the future work of that committee is to be based. This is one step toward international agreement regarding methods of appraising the merit of the various fluorescent lamps available in world markets.

Specular Reflectance Standard. In cooperation with the Bureau's enameled metals laboratory and the Army Engineer Research and Development Laboratory, a spectral directional reflectance study was made of a number of metals and evaporated metal films on glass. The work was undertaken to find a suitable standard of specular reflectance in the ultraviolet, visible, and near infrared spectra. It was found that a deposit of rhodium on glass gave the best promise of being a permanent standard. This tentative standard was used in a cooperative test for the University of Wisconsin, in their work on the solar effect on soils.

Color Scale for Vegetable Oils. For many years Lovibond red glasses have been calibrated for use in measuring the colors of vegetable oils (cottonseed, peanut, palm) for commercial evaluation. These calibrations have been based on a Bureau scale (Priest-Gibson) set up in 1927. As a result of negotiations between the American Oil Chemists Society and the makers of Lovibond glasses, and based on NBS color measurements, an AOCS color scale has been established for the vegetable-oil industry in this country. It is anticipated that the manufacturer will be able to supply working standards of color to the American vegetable-oil industry which will agree with current practice and that future Bureau calibrations will not be required.

Refractive Indices Provided. The critical components of most optical instruments are the lenses, prisms, and windows. Designers of infrared and ultraviolet devices must have accurate values of refractive index of all available transparent materials to select optimum materials and designs for such components. In a continuing program to provide such information, the index of refraction of a natural and a synthetic prism of calcium fluoride was measured over a wide range of wavelengths (0.23 to 10μ) at several temperatures. The refractive index of six experimental infrared glasses developed at NBS was also determined. Various components of a vacuum monochromator system, used in extending the measurement of refractive index and other optical properties of transparent materials into the short wavelength region of the spectrum, were installed and tested.

Image Analysis. The evaluation of imagery concept was extended to include the measurement of lens resolution in terms of frequency response using either sine wave or square wave targets. In this method, the aerial image of an infinitely distant target is scanned by a slit and photocell to read out variations in image intensity. The lens is then treated as a low pass filter of spatial frequencies and response is determined by comparing the calibrated with the modulated image.

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Ray-Tracing Equations Developed. In the last decade a new principle in optical design, called common path interference, has been introduced and applied to interference microscopes and lens testing interferometers. These devices have double-focus lenses made of uniaxial crystals that divide a beam of light into ordinary and extraordinary rays. The design of a common path interference device is based on the difference in refraction of these two rays. However, because simple ray-tracing equations for the extraordinary ray were not available, few double-focus lenses have been designed.

The Bureau therefore developed equations which are not much more difficult to apply than are those employed for skew rays. Moreover, they make use of data from an ordinary ray-tracing program. These equations are derived from the purely geometric point of view. They presuppose a knowledge of the ordinary ray, obtainable from ordinary ray-tracing procedures together with the normal to the refracting surface. In the final derivation both Huygen's principle and the ellipsoidal indicatrix for a uniaxial crystal are employed.

Interference Microscope Techniques. In recent measurements of very fine surface finishes on prepared steel surfaces, it was found that two-beam interference microscopy did not provide sufficient resolution to distinguish small differences. Hence, commercial metallurgical microscope components were employed to produce multiple-beam interference and achieve the desired resolution. These components consist of cover glass slides, coated for maximum reflectivity on one side with zinc sulfide and coated on the other side for minimum reflectivity with cryolite. The technique was applied to the study of surface finishes on spherical surfaces of 0.5-inch radius and on cylindrical surfaces of 0.002-inch radius.

Absolute Testing of Wavefront Shapes. A method was developed for making absolute tests by interferometry. The process compares (1) an unknown wavefront with a sheared image of itself, or (2) one part of a wavefront with one or more different parts of the same wavefront, or (3) different parts of one wavefront with another unknown wavefront. A unique solution is then obtainable by combining simple mathematical operations. This manner of compounding interferometry with mathematical operations eliminates the need for reference standards and thus improves the accuracy of the results obtained. The process has been tested and reports have been prepared on the absolute testing of wavefront shapes that are characteristic of aberrations of lenses and lens systems (entire optical imaging forming units); shapes of optical mirrors; and image quality of simple or compound optical systems.

Calibration of Crash Flight Record. Jet aircraft are required to carry an automatic flight recorder which makes a permanent graph record of such parameters as air speed, altitude, azimuth, and acceleration as a function of time. One of these recorders, retrieved from the crash of an aircraft in New York in December 1960, was submitted to the Bureau for calibration of the record. Such a calibration consists of measuring the co-

Experimental one-pan balance designed to investigate the limitations of such an apparatus in experiments where the maximum attainable level of precision is demanded—work with the National Standard Kilogram, for example (page 22).

ordinates at numerous positions of traces made by diamond stylii on a metal foil capable of retaining the record and of maintaining its mechanical strength after exposure to fire, shock, and salt water immersion. The Bureau succeeded in extracting the record from the battered recorder, removing the heavy carbon and polymer deposits from the portion of the foil showing the latest recording from Chicago to New York, measuring the coordinates of the traces, and with the help of the manufacturers and the Civil Aeronautics Board, interpreting the measurements as quantitative and correlated values of the parameters which they represented.

Photographic Density Measurements. Fine photography in science, industry, and art largely depends on the photographic effect on a film of a given exposure. To determine the optical density of these films, photo-

graphic step tablets calibrated at the Bureau are made available for calibrating the transmission densitometers used to measure optical density. During the past year, the apparatus and method used for calibrating step tablets were refined so that the uncertainty of measurements previously ranging from 0.02 to 0.09 on the density scale were reduced to 0.01.

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

Because of the increasing requirements for measuring mechanical quantities in defense industries and in government laboratories, and because of the requirements of missile and space projects, requests for calibration services continued to increase. For example, during the year, more devices for measuring force and flow were calibrated than in any previous year.

Measurement of Vibration Amplitudes. The calibration of vibration pickups, used for measuring vibrations in machines, missiles, satellites, and aircraft, can now be accomplished by means of a recently developed photometric system. The amplitude of vibration of one plate of a Fizeau optical interferometer is deduced from photometric measurements on the interference pattern. This new technique was used to calibrate pickups over the audiofrequency range and amplitude range 72–4400 Angstroms (0.3–17.3 microinches), with estimated errors no greater than 2 percent. Vibration amplitudes as small as 5 A (0.02 μin.) can be measured with uncertainties no greater than 10 percent.

Calibration of Microphones. Condenser microphones calibrated by the reciprocity technique serve as the basic standard instruments for measurement of sound pressure over a wide range of frequencies. A simple method was developed for measuring the relative response of a microphone by means of carrier-frequency circuits. First of all, diaphragm motion is brought about by voltage of various frequencies applied to the microphone. Then the carrier-frequency measurement yields relative response over the frequency

range from 1 cycle per second to 50,000 cycles per second. The absolute response can be determined at any convenient frequency by means of reciprocity technique, and is then readily computed for other frequencies from the relative response determined by the new technique.

Recording on Magnetic Tapes. A recording on magnetic tape undergoes amplitude and phase changes at frequencies near the upper limit of the pass band for the entire record-tape-playback system. For recordings of speech or music, phase distortion is not a serious drawback since a person's hearing is relatively insensitive to this effect. But the amplitude-equalizing circuits frequently used in tape systems cause an intolerable amount of phase distortion on tapes used for recording of data from measuring instruments. In work sponsored by Patrick Air Force Base, a method for minimizing this distortion was developed, thus allowing the more accurate reproduction of complex waveforms. A new equalizer which is used can be regarded as a filter consisting of an amplitude-equalizing network, followed by an all-pass phase-shift network. The method will facilitate researches into short-wavelength recording on magnetic tapes.

Analysis of Transients. Signals of importance in acoustics can be studied as waveforms of voltage varying as a function of time, but are usually contaminated with noise. It has been found, moreover, that there are limitations on the amount of information, about the distribution of sinusoids, which can be deduced in a finite time interval from a noise-contaminated signal. The limitation depends only on the signal-to-noise energy ratio at the input to the system. The distribution of the sinusoidal components is found by analysis using a filter system. It appears from a study sponsored by the Office of Naval Research that uncertainty in determination of a sinusoidal component with any filter system is never less than that resulting from analysis with a simple damped resonator.

Infrasonic Waves in the Atmosphere and in the Earth. Researchers on naturally occurring infrasonic sound waves in the atmosphere disclosed that those generated by geomagnetic storms approach Washington from directions which vary during the course of the day. The variations suggest that the source of sound in the upper atmosphere is approximately fixed relative to the sun. The earth rotates under the source and thus the source seems to move over the earth's surface.

Preliminary measurements on infrasonic waves having quite constant periods—near 6 seconds—showed that these waves usually come from easterly directions, and seem to travel through the atmosphere almost parallel to the earth's surface. These atmospheric waves, usually called microbaroms, occur often in the Washington area.

Research having to do with infrasonic waves in the earth also was carried on during the year. This research was aided by a reliable instrument system for measuring vibrations of the earth, developed from study of the electromechanical equations of motion of a seismometer-galvanometer system. The seismometer itself is stable with respect to variations in the local gravitational

Calibrating an infrasonic microphone (front, connected by a hose to the calibrating barrel) used to study naturally occurring infrasonic sound waves in the atmosphere (page 29).

field, as well as for large variations in barometric pressure, and temperature changes in the range −40 °F to 120 °F. The instrument was designed for the pass band 1 to 5 cycles per second with a system noise level at least one decade lower than the seismic noise at the quietest known location on the earth's surface. It can be used for other pass bands at some sacrifice of signal-to-noise ratio.

It is planned to use at least three of these systems in the Washington area with seismometers spaced far enough apart to allow determination of the propagation speed and direction for microseism waves in the earth's crust. Such waves have periods of about 6 seconds, as do the microbarom waves in the atmosphere. The origins and interactions of these two types of waves are still obscure and require elucidation.

Ultra-High-Pressure Measurements. Work continued with the multiple anvil devices capable of generating pressures in excess of a million pounds per square inch. The technique of preparation of the samples and operation of the apparatus was refined until the pressures reached in an experiment can be predicted within a few percent, as compared with 20 percent a year ago. A device using six anvils pressing on the faces of a cube was put into operation. This can reach pressures nearly as high as those obtained with the four-anvil tetrahedral apparatus. With the six-anvil

device the pressures are more nearly hydrostatic and somewhat more reproducible.

Study of Convective Currents in Water. In an investigation of possible methods for detecting motions within a body of water, schlieren optical techniques, commonly used to observe shock waves in supersonic aerodynamics, were found to be so sensitive that convection currents resulting from evaporative cooling at the surface could be studied in detail. The schlieren method proved to be important in detecting and measuring motion involving temperature differences as little as 0.01 °C and possibly smaller. The phenomenon observed was a pattern of plunging currents resulting from instability of the cooled surface layer.

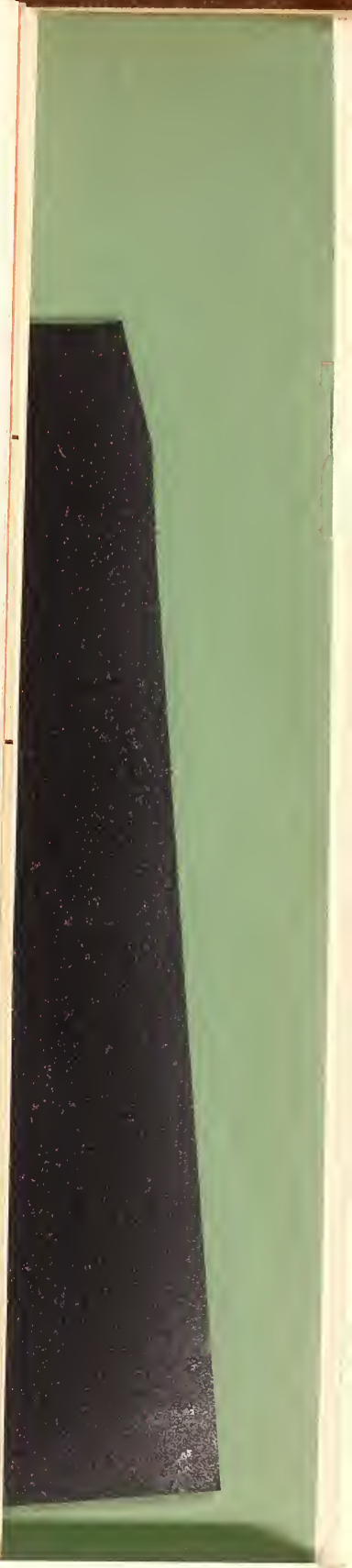
When a container of still water was first uncovered, a cooled surface layer was seen to develop. Within seconds, local thickening developed along irregular lines; and in these regions the cooled liquid plunged in descending sheets. Simultaneous photographs from the top and side of a glass container revealed configurations which changed slowly with time but persisted indefinitely. Independent measurements of the temperature gradient determined the conditions under which instability of the surface layer set in and conditions for maintaining the currents. Thus, in what to the naked eye appeared to be still water, there were usually present the sharply defined sheet-like currents descending through the surrounding water whenever evaporation was taking place from the surface.

Internal Waves in Water with Uniform Density Gradients. As part of an investigation of internal waves, sponsored by the Office of Naval Research, the phenomenon of wave production was studied when there existed a uniform density increase from the surface downward. It was known beforehand that waves would form at the interface between two distinct layers of different density much as they do at a water surface. The year's work showed that motions wavelike in character also ensued due to the movement of a body through liquid when there was a uniform variation in density.

The body in this case was a lenticular cylinder moved through water 50 centimeters deep in a long channel. A density gradient from top to bottom was produced by varying the salinity. The motions were observed in part by instruments and in part by photographic techniques through dyeing alternate layers to produce a field of parallel stripes.

Force Measurements. The advent of missiles and space exploration has led to requirements for load or force measurements that exceed the Bureau's present capabilities for accuracy and magnitude. To meet these needs three new dead weight machines of 113,000-lb, 300,000-lb and 1,000,000-lb capacities will be installed in the new Engineering Mechanics Laboratory at Gaithersburg, Maryland to supplement the two existing machines of 10,100-lb and 111,000-lb capacities. Meanwhile, the existing machines will be modernized before being moved to Gaithersburg.

During the year the designs of the new dead weight machines were almost completed and some of the major components were under contract. These



machines will apply loads accurate to 0.01 percent or better in tension and compression.

The Bureau's 1,000,000-lb and 3,000,000-lb elastic load-measuring devices were recalibrated and used to calibrate a load cell to 6,000,000 lb. This is though to be the largest portable load measuring device in existence. It is believed that the error of the applied loads did not exceed 0.3 percent.

Clamping Force of High-Strength Aircraft Bolts. At the request of the Bureau of Naval Weapons, tests were made to determine the feasibility of predicting the clamping force of an installed high-strength aircraft bolt by measuring the amount of torque applied to the nut or bolt under dry and lubricated conditions. This method has long been in use for installing non-lubricated low- and intermediate-strength aircraft bolts, but limited data are available for the intermediate-strength type.

Tests were carried out during the year to evaluate performance of a special machine for applying torques, and of special load cells for measuring torque and clamping force. Modifications were made to obtain optimum performance. The relationships between torque and clamping force were determined for two diameters of bolts with minimum tensile strengths of 180,000 lb/in.^{2} when used as fasteners of aluminum, steel, and titanium joints.

Mechanical Properties of Materials at Elevated Temperatures. Nose cones of manned spacecraft should be fabricated from materials which can withstand very high temperatures without loss of structural integrity and

Diamond grown in multi-anvil (tetrahedral) apparatus at a temperature of 3000 °F and one million pounds per square inch pressure. This work is aimed at establishing fixed reference points on the pressure scale (page 30).

which will dissipate heat by radiation. This will be particularly critical when such craft must make more than a single flight.

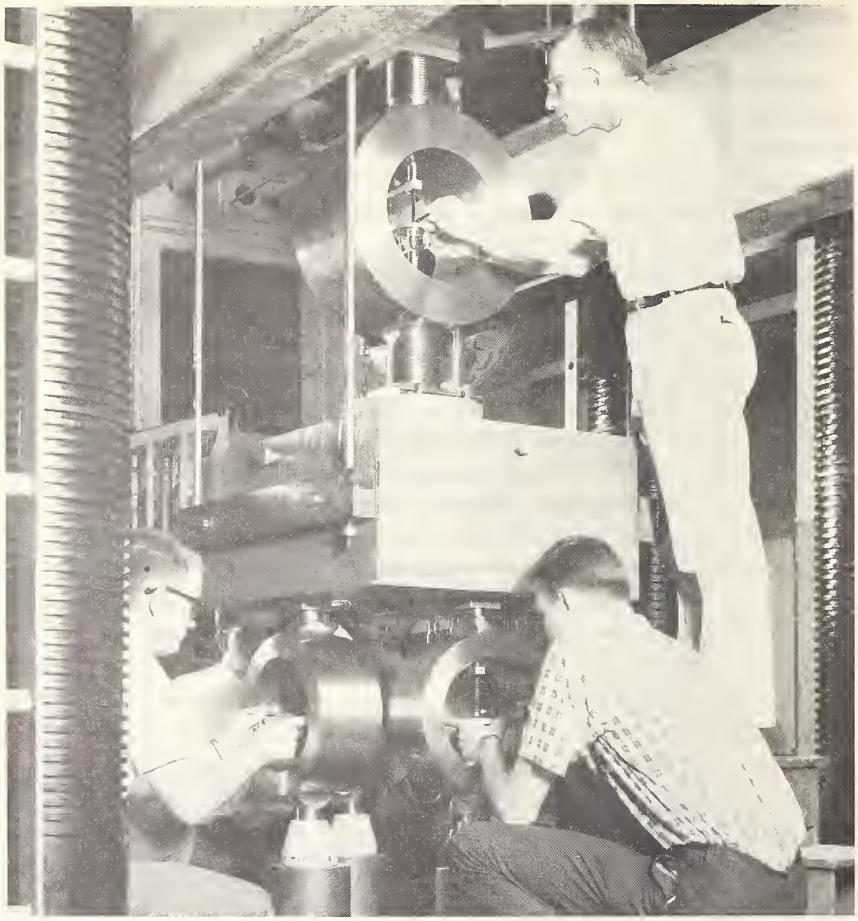
To provide means of evaluating materials for this purpose, apparatus and techniques for conducting mechanical tests at temperatures approaching the melting points of the refractory metals were developed under a program supported in part by the Office of Naval Research. An optical technique for accurate measurement of strain was pursued for use on tensile specimens tested at 3,000 to 4,000 °F in a vacuum. Using carefully selected filters, water-cooled viewing ports, and motorized cameras, high-resolution photographs of the specimens were made; and the relative displacements of grid lines on the specimen surfaces were measured with reference to a fixed fiduciary grid network which was a part of the optical system.

Rheology of Liquids. Rheology, which is the study of the flow of various materials, is important for an understanding of the behavior of these materials. One phase of rheological study at NBS concerned a mathematical bounding technique, which permits the calculation of exact limits for the effects of inertia on certain flows. The technique was described in 1960 "Research Highlights" (p. 55). Further applications of this technique were investigated during the year with the objective of establishing limits on inertial effects for selected flow geometries. A first step toward the separation of rheological nonlinearities from thermal effects was accomplished through the calculation of the effect of viscous heating on the flow through a pipe of a liquid whose viscosity varied exponentially with temperature. The results suggested that certain experimental observations generally attributed to nonlinear constitutive equations of the material might be due instead to these thermal effects. Further calculations for a geometry which should permit a definitive experimental verification are underway.

New measuring techniques which will permit the absolute measurement of the viscosity of a liquid by eliminating inertial effects from the measured quantities are also under development. These techniques will still require some independent estimate of the magnitude of possible thermal effects.

Additional information on the relation of the effects of temperature and pressure on the rheological properties of rubberlike polymers, which are essentially complicated liquids, was obtained through the study of the complex bulk compliance of polyvinyl acetate. These results suggested that the free volume concept, which has led to a simple presentation of the influence of temperature on the rheological properties of a wide variety of polymers and the effect of pressure on these properties for a limited number of polymers, may need some modification or elaboration.

High-Temperature Thermocouples. Measurements of thermal emf were completed on thermocouples of 40 percent iridium-60 percent rhodium versus iridium at temperatures up to 3,800 °F. Reference tables were compiled for this combination. Work was continued, using the same experimental procedure, on alloys of iridium with 40 and 50 percent rhodium against iridium.



Calibrating the world's largest proving ring, capable of measuring forces up to 1,200,000 lb. With present facilities, the Bureau can calibrate such devices only to 110,000 lb. with deadweights; beyond that, indirect methods are used, with a resulting loss of accuracy. Three deadweight machines, the largest having a capacity of 1,000,000 lb., are being designed for the new NBS laboratories in order to increase the accuracy of such calibrations (page 31).

Catalytic Effects of Thermocouple Materials. In analysis of many industrial processes involving combustion of fuels such as hydrocarbons in air, it is often necessary to determine the temperature of exhaust products containing appreciable amounts of combustible gases and oxygen. This is particularly true in performance evaluations of gas-turbine power plants.

In this connection, it has long been known that platinum is a fairly good catalyst for many oxidation reactions; and early work at NBS showed a platinum shielded Chromel-Alumel thermocouple to indicate as much as 25 °F higher than the temperature of exhaust gases containing a small amount of unburned hydrocarbon. As a result of these findings, the Aeronautical Systems Division of the Air Force sponsored a program at NBS to determine the catalytic effects of all of the commonly used thermocouple materials.

The experimental technique utilized the resistance of electrically heated test wires of thermocouple elements to determine their temperatures. Power requirements at given wire temperatures were compared for low-velocity streams of dry air and of combustible mixtures to determine the magnitude of the thermal contribution from catalytic combustion. Experiments were conducted in mixtures containing up to 3 percent by volume of hydrogen, carbon monoxide, methane, and propane in air flowing at gas velocities from 0.16 to 4.38 cm/s over the resistance element.

No catalysis was exhibited by resistance elements made of gold, silver, Chromel, Alumel, or constantan. However, all resistance elements containing either platinum or palladium catalyzed the reaction of all combustible mixtures tested except those of methane. The magnitudes of the catalytic effects and their temperature limits, up to 2,000 °F, were determined; and some anomalous behaviors were explained.

Hypervelocity Missile in a Combustible Gas. Stabilization of hypersonic combustion appears to be a prelude to its application to propulsion at hypersonic speed. With a view to this application, research on stabilization and properties of this kind of combustion continued by observation of a hypervelocity missile in a stationary combustible gas. In this program, sponsored by the Air Force, experiments showed that, as in nearly all combustion processes, oscillations driven by combustion may be expected at extremely high frequency. The likelihood of generation of thrust by combustion on external missile surfaces is suggested by a large reduction of the drag coefficient of the missile under certain conditions.

The experimental technique developed for these studies also permitted observations on the structure of detonation waves. Detonation appears as a shock wave followed by a combustion wave. The observed spatial separation was converted to ignition delay times, which in these experiments ranged from about one to ten microseconds. Chemical kinetics of chain-branching and chain-breaking reactions in the mixture of hydrogen and air were used to correlate and explain the observed delays.

Fuel Flowrate Studies. Under sponsorship of the Bureau of Naval Weapons, progress continued on the fuel flowrate standardization program for the aircraft industry, and on the evaluation of flowmeters. Many transfer reference meters were calibrated with liquid hydrocarbons for the Armed Services and for industry, in order to evaluate the accuracy of calibrators installed at other locations. The results of investigations over the past several years on turbine flowmeters were summarized for publication. It was shown that metering precision better than 0.2 percent was obtained for selected ranges of flowrate and viscosity when entrance conditions and meter orientation were suitably controlled. The readout instrumentation and transient response were also discussed.

Through such work more accurate flowrate calibration facilities are being maintained in the aircraft industry, and more suitable fuel flowmeters are being developed and manufactured.

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 the study of the electrical and magnetic properties of materials. 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 comparision with these electrical standards.

Absolute Measurement of Resistance. An evaluation, based on the prototype standards of length and time, of the unit of resistance maintained at the Bureau was completed. The evaluation was based on a nominally 1-picofarad symmetrical cross capacitor having a value computable to high accuracy from its mechanical dimensions. The computable capacitor was used to establish the value of a 0.01-microfarad capacitor which then, through the medium of a frequency-dependent bridge, established the value of a 10,000-ohm resistor. A comparision of that resistor with the group of 1-ohm standard resistors currently used to maintain the NBS unit of resistance established the value of the unit with an estimated accuracy of the order of 2 ppm.

It is expected that an even higher accuracy will be attained in the repetition of these measurements. This method will greatly improve the Bureau's ability to check maintenance of the unit of electrical resistance through the use of a group of standard resistors. When combined with repetitions of determinations of the gyromagnetic ratio of the proton, the method can be used as a check of the stability of all types of electrical standards to a much greater accuracy than previously possible.

Standard Cells Under Vibration. Standard cells are normally used under vibration-free conditions. Even so, the question frequently arises as to the effect of vibration on the electromotive force of standard cells. The Bureau exposed a number of unsaturated standard cells to vibrations at frequencies from 5 to 2,000 c/s and applied forces from 1 to 30 g. With a d-c galvanometer used as null detector, such vibrations appeared to have insignificant effects. However, when observations were made with a cathode-ray oscilloscope, an a-c voltage was observed. At frequencies above 150 c/s, the magnitude of the a-c voltage appeared to be dependent on the applied force and to range from 20 to 120 microvolts. At frequencies below 150 c/s, the magnitude of the a-c voltage was no longer proportional to the applied force because of the resonance of various components, especially free mercury above the cell septa. Vibrations of these magnitudes have no lasting effects on the electromotive force unless the cells are quite old or exhibit excessive hysteresis; in such cases several days may be required for the cells to recover their initial electromotive force.

Electrode Kinetics. Electrode reaction mechanisms may be studied in many ways. One method, presently under consideration at the Bureau, involves the measurement of the impedance of electrode-electrolyte systems as a function of the frequency of an applied alternating field. The kinetics were studied in terms of electrode relaxation processes using alternating currents of frequencies from 50 c/s to 50 kc/s. Electrodes studied included silver, cadmium, zinc, and manganese dioxide. The last two electrodes were also studied in combination in dry cell electrolytes. Equations based on electrostatics and electrodynamics were developed to explain observed phenomena. Two electrode processes occur at manganese dioxide electrodes; whereas a single process, namely, simple charge transfer, occurs at the other electrodes. The exchange currents of silver in silver nitrate and of cadmium in cadmium sulfate were found from impedance measurements at low and high frequencies to be 110 amp/m^2 and 140 amp/m^2, respectively.

Assembling the gage blocks used to form the NBS computable cross capacitor. The capacitor was used to re-evaluate fundamental unit of resistance in terms of the prototype standards of length and time (page 36).

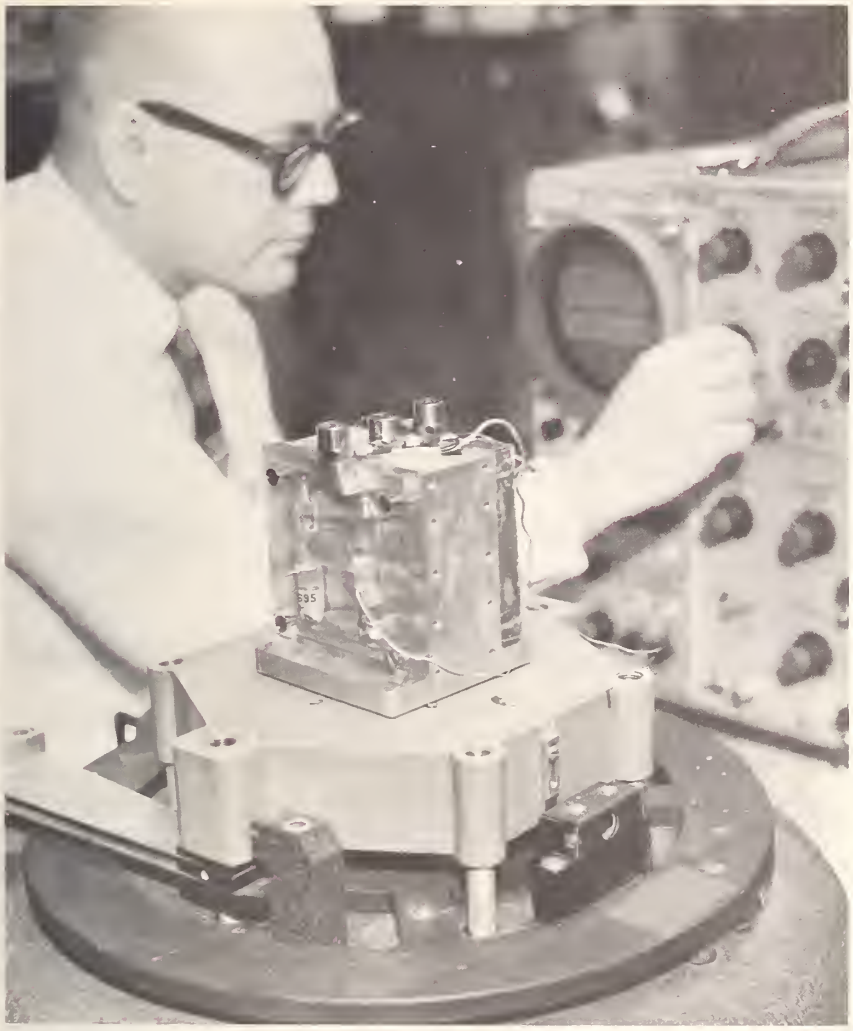
Electrical Properties of Molecular Solvents at High Temperature. There are very few data on the behavior of dilute solutions of electrolytes in molecular solvents at high temperatures. Nonionic solvents at high temperatures are few in number and there is a need for extensive study of their properties. At present, the dielectric constant of boric oxide is under study at the Bureau. At frequencies from 1 to 2 kc/s, both dielectric constant and loss increase sharply above 500 °C; the dielectric constant rises to above 300 at 900 °C, indicating that very large units of the three-dimensional boric oxide must be inferred if one is to interpret the electrolytic conductivity and the interionic attractions of salt solutions made with boric oxide solvent. Measurements of these values are now in progress.

Metal Oxide Solubilities in Molten Salts. Electrochemical corrosion of metals in molten salts at elevated temperatures is greatly influenced by the oxygen content of the environment. As a part of a broad study on this problem, the Bureau determined the solubility of the oxides of the metals of the first transition series (titanium, vanadium, chromium, manganese, iron, cobalt, nickel, and copper) in molten sodium chloride at 900 °C. Vanadium pentoxide reacts violently with molten sodium chloride to form chlorine, whereas the oxides of the other first transition metals are stable and only slightly soluble (less than 0.1 mole percent) in molten sodium chloride. Results for Cu_2O, CoO, and Mn_3O_4 indicated that the mechanism of dissolution is complex, since the metal-oxide ion ratio is several times greater than would be expected for a simple solution process. Furthermore, the solubilities of the oxides, although low, are much greater than would be indicated by thermodynamic calculations.

Metal-Molten Salt Interactions and Stoichiometry. Extensive mass transfer is commonly observed for metals immersed in molten salts at elevated temperatures. Such transfer limits the use of molten salts as heat exchangers and the range of use of reference electrodes in molten salt systems. Reactions between silver and molten sodium chloride were investigated at 820 °C and 940 °C in a pure oxygen atmosphere and in a nearly oxygen-free (10^{-5} atm) environment. In each case, silver and oxide ions are formed in the melt with the concentration of the silver ions exceeding that expected from the stoichiometry of monovalent silver oxide. At low oxygen pressures, less than 0.2 atm, the rate of silver-oxygen interaction is zero, or independent of the oxygen pressure. At higher oxygen pressures, the rate is controlled by diffusion of reaction products away from the reaction site. If the solubility product of the oxide is exceeded locally by slowness of diffusion, metallic silver crystallizes out since the oxide is unstable. This process accounts for extensive mass transfer of metallic silver in molten sodium chloride.

Differential Thermocouple Voltmeter. A basic problem in electrical standardizing laboratories is the transition from d-c measurements (which are closely related to the fundamental standards) to a-c measurements at power and higher frequencies.

A recent contribution of the Bureau to the solution of this problem consists of the development of a "differential thermocouple voltmeter." This



A study of the effects of vibration on the performance of standard cells showed that an a-c voltage was produced during vibration, but that no permanent damage resulted (page 36).

instrument includes two equal thermoelements, one supplied by an unknown voltage and the other supplied by a highly stable reference voltage. The thermoelement supplied by the unknown voltage is in series with a decade resistor. The dials of this resistor are read directly in volts and so can be set to indicate the nominal value of the unknown voltage. The percentage difference between the unknown voltage and its nominal value as determined from comparison with the reference voltage is then read directly on a galvanometer.

Magnetism. The nuclear magnetic resonance of Ni^{61} was observed in 99.97 percent pure nickel metal. It was found that the resonance occurs

at a frequency of 26.1 Mc/s at room temperature with a line width of about 50 kc/s. The temperature dependence of the frequency was measured over a temperature range from 77 to 536 °K, and the effect of an externally applied field on the intensity of resonance was observed. The Ni^{61} resonance was also observed in 99.7 percent pure nickel with substantially the same results as with the purer sample. Studies are in progress on the resonance in nickel-rich alloys.

A special susceptibility apparatus was constructed for measuring the absolute susceptibility of small samples (less than 0.5 gram) and single crystals by means of a quartz beam balance. This apparatus is designed to measure the primary static susceptibilities of paramagnetic substances while a given microwave magnetic field is being applied. The apparatus also provides for relative measurement of greater sensitivity of susceptibilities by use of a vibrating magnetometer method. Preliminary measurements are now being made with the apparatus of the primary susceptibility of single crystals grown in this laboratory.

Analysis of the Melting Point of Polychlorotrifluoroethylene. The observed melting point of the linear polymer polychlorotrifluoroethylene was experimentally determined to depend strongly on its original crystallization temperature. The observed melting point rises with crystallization temperature. (Results of this type have been known in other polymers for many years.) This interesting phenomenon was explained in terms of the behavior of chain-folded crystals, and the experimental data were used to estimate the equilibrium melting temperature of the polymer.

Analysis of the Dielectric Properties of Polychlorotrifluoroethylene. Data obtained from a previous detailed experimental study on polychlorotrifluoroethylene were analyzed to reveal the contributions of the crystalline and amorphous regions of this semicrystalline polymer. One of the loss processes in the polymer is associated with the freezing out of long-range molecular motions that are associated with the onset of the glass transition in the amorphous component at 52 °C. At a given frequency, say 1 c/s, the dielectric loss peak associated with this mechanism corresponds closely with a mechanical loss peak observed by others. The activation energy exhibited by this process is large and strongly dependent on temperature. At low temperatures, far below the glass transition, the amorphous component exhibits an additional and very prominent dielectric loss mechanism, which is a result of short-range motions in the glassy state of the polymer. The activation energy of this process is small (about 60 kj/mole) and independent of temperature. This process also possesses a mechanical analog—the crystals in the polymer exhibit a marked dielectric polarization which is associated with a very rapid dipolar re-orientation process, probably a twisting mode. Evidence exists that in highly crystalline specimens the amorphous material still remaining has somewhat abnormal properties. Foremost among these is an elevated glass transition temperature. The properties of the liquid polymer above the melting point, which is 221 °C, exhibit the customary negative temperature coefficient.

Finding the frequency response of a differential thermocouple voltmeter. This instrument is a recent contribution to the solution of the problem of transfer from d-c and a-c measurements at power and higher frequencies (page 38).

Dielectric Properties of Polyparachlorostyrene and Polymetachlorostyrene. Polyparachlorostyrene is a molecule which, in effect, has a large dipole moment that is attached at a right angle to the main polymer chain backbone. Thus, a motion of the main chain is required to permit reorientation of the dipole moment and dielectric loss. Dielectric measurements on this noncrystalline polymer in the glassy state reveal no evidence of molecular motion, even at low frequencies.

The situation is radically different in the case of polymetachlorostyrene. In this material, dipolar orientation can be effected by allowing the benzene ring side group to turn about the bond connecting it to the polymer chain backbone. Dielectric measurements have confirmed that such a motion exists even well below the glass transition temperature, since a large dielectric loss is observed. This work discloses an excellent example of dielectric loss due to hindered internal rotation in a polar side group substituent on a polymer chain.

2.1.4. RADIO STANDARDS

The Bureau program in radio standards, centered at the Boulder Laboratories, consists of basic research and development of national standards of fundamental electromagnetic quantities, measurement techniques, and properties of materials. A large calibration service is provided from direct

current through microwave frequencies, and radio broadcasts are made of the national primary standards of frequency and time intervals.

Probably the most striking developments during the past year, scientifically and internationally, were in the area of frequency standards. International comparisions of the atomic beam frequency standards of the United States, England, and Switzerland indicate continued agreement to within 1 or 2 parts in 10^{10}. The United States standard has also been compared daily with commercial standards and has operated on a routine basis throughout the year. All indications are that the United States Frequency Standard is performing at the estimated level of stability. This performance, and the performance of frequency standards in other parts of the world, has led to active consideration on the international level of a redefinition of the second in terms of an atomic transition.

During the year several conferences designed to define and resolve major problems in electronic measurement were held. A series of measurement research conferences between industry and NBS, initiated by the Aerospace Industries Association, is continuing to probe each field of measurement in depth. In the area of electronic measurement the first such conference was held during May 1960, and considered measurement and calibration problems in the fields of microwave power and attenuation. Additional conferences in this area were held during January and June 1961, and considered the same problems in the fields of pulsed signals, sinewave rf signals, and rf and microwave noise and impedance. These conferences help define what ranges and accuracies are most needed in these fields, why they are needed, and what immediate and long-range action might best be taken by the Bureau, industry, the military, and scientific organizations.

At the suggestion of several defense agencies, the Electronic Calibration Center provided a 5-day workshop—covering microwave frequencies—for about 40 technical supervisors from a large number of standards laboratories in the Department of Defense. Basic theory of the precision measurement of power, impedance, frequency, attenuation, and noise was covered in half-day sessions for each quantity. Equal time was spent in the laboratory to provide the opporunity of viewing measurement equipment in actual use. This kind of effort, by improving measurement competence in laboratories of industry and defense, multiplies the effectiveness of NBS.

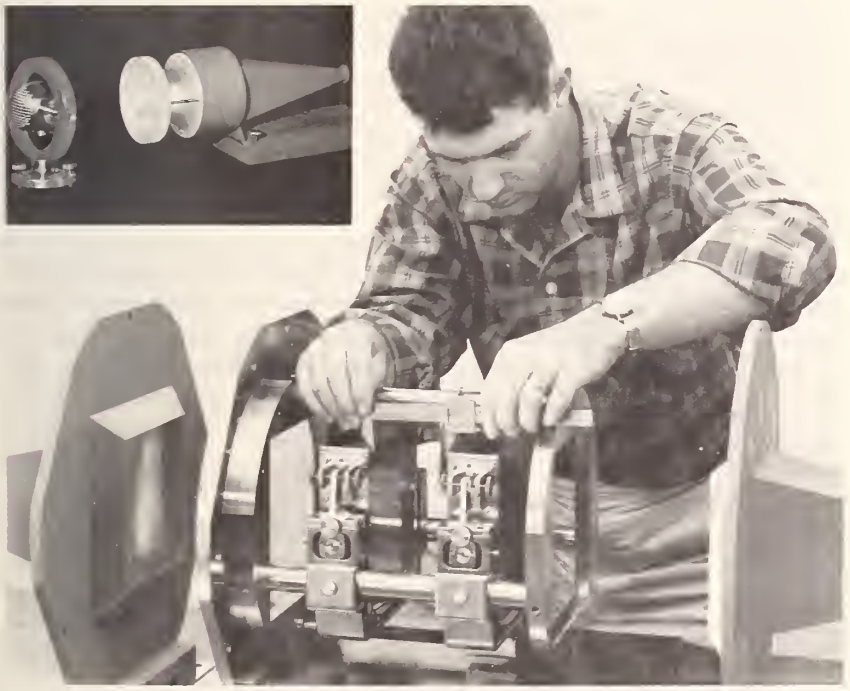
The Bureau also served as host for a meeting on high precision connectors. It is expected that the ideas expressed at this meeting—by different manufacturers and NBS—will lead to much better measurement equipment in this field and to a standardization of the instruments and techniques involved.

Theoretical Physics. Studies in theoretical physics and applied mathematics (including numerical analysis) contribute to the more basic work of the entire radio standards program. These studies are an end product in themselves and, on occasion, provide key theoretical developments upon which further work in other projects may be based.

Perturbation formulas, based on a "compensation theorem" stated for waveguide junctions, were used to obtain approximate results in a variety of waveguide problems. One such problem, for example, was that of reflection at the junction of a perfectly rectangular waveguide with a filleted rectangular waveguide of the same main dimensions. The theoretical results of this problem are being compared with NBS experimental results. The perturbation formulas were also applied to theoretical results which are already available and it was found that the common expedient of using an unperturbed field, as an approximation to an unknown field, does not always lead to a correct lowest-order approximation.

Radio Plasmas. Radio waves and plasmas are intimately connected in that each can be used as a tool to study the other. For example, radio waves are used to create plasmas and to determine their properties; plasmas are used in such microwave devices as TR switches, noise sources, modulators, couplers, and harmonic generators.

A current objective in this area is to understand all modes for the propagation of energy through plasmas, including both electromagnetic and plasma waves. Theoretical and experimental progress was made in understanding the many possible electromagnetic modes in a cylindrical plasma, and especially the effect of placing bounding surfaces on a medium supporting the "whistler" mode.



A Fabry-Perot Interferometer, designed to operate at millimeter wavelengths, is being used as the cavity resonator for a hydrogen cyanide gaseous maser. The device shows promise for frequency standard applications, and in microwave spectroscopy. Bi-conical, spherical cavity (inset) illustrates the design flexibility of the perforated cavities (page 44).

Atomic Frequency and Time Interval Standards. The previously observed difference of 1.5×10^{-11} between the two NBS atomic frequency standards was carefully remeasured and found to have remained constant to at least 2×10^{-12} over the year. In an initial experiment with thallium, a thallium beam was successfully detected but with low efficiency. Experiments which used an ammonia maser to excite the cesium resonance resulted in measurement precisions of 3×10^{-12} in periods of only a few minutes.

In these measurements precision refers to the reproductibility of several consecutive measurements of a very stable oscillator. Each such measurement may require several minutes and consists of an average of 15–25 separate determinations of the oscillator frequency. The accuracy of the NBS standards is considered to be 1×10^{-11} and refers to the maximum expected deviation of the measured frequency of either standard from the idealized Bohr atomic resonance frequency. The accuracy estimate is obtained by adding up all uncertainties associated with certain parameters in the system which may affect the measured frequency.

A servo system for locking a 5 Mc/s quartz crystal oscillator to the cesium atomic resonance was completed and extensively tested. The system operated satisfactorily although a small, systematic frequency shift may be introduced if proper precautions are not taken. Tests were begun on a servo system for the second cesium standard.

Refinements of an ammonia beam maser permits the maser frequency to be reset to about 3 parts in 10^{11} by comparison with the cesium beam. This was accomplished by construction of a new servo system which constantly controls the cavity tuning of the maser. The correction signal is obtained by Zeeman modulation of the ammonia line. With this development the ammonia maser can be seriously considered as a secondary standard of frequency.

A Fabry-Perot maser was constructed which offers the potential of a highly-stable signal source, at millimeter wavelengths, for frequency standard applications, and for applications in microwave spectroscopy—both maser and absorption spectroscopy—at similar high frequencies. This instrument, a hydrogen cyanide gaseous maser, is designed to operate at a wavelength of 3–4 millimeters and uses a millimeter wave Fabry-Perot interferometer in place of the conventional cavity resonator. The Q of the interferometer was observed to be 32,000, and work is in progress to observe maser oscillation at 88.6 Gc/s.

Construction was begun on a new beam tube to increase the length of the U.S. Frequency Standard apparatus, and thus reduce the spectral line width by a factor of ½; on a third atomic beam frequency standard which will have an oscillating field separation of about three meters; and on a hydrogen atomic beam maser which should have a higher ultimate stability, at microwave frequencies, than existing masers.

Radio Broadcast Service. Propagation data continue to demonstrate that low and very low frequencies, because of their high phase stability, are a much more accurate method of distributing standard frequencies over great

distances than the short wave broadcasts of WWV and WWVH. The lower frequencies also offer the potential of greatly increasing the accuracy of time signal transmission. This is of particular importance to the satellite and missile programs of the armed forces and of the National Aeronautics and Space Administration.

Therefore, substantial effort is being devoted to the establishment of a 20- and 60-kc/s station at Fort Collins, Colo., which will have a much higher radiated power than the existing stations near Boulder. The 60-kc/s transmission will include precise time information, and both transmissions will be directly controlled by the U.S. Frequency Standard (USFS). Designs have been established for the major components of both transmissions, and contracts were let for many of the 20-kc/s components.

The standard frequency 20-kc/s transmissions from WWVL, Sunset, Colo. (about 20 miles from Boulder), have been given continuously, as scheduled, since April 1960. Broadcasts were monitored in Boulder by three different methods, all methods were referred to the USFS, and all results were the same except for very small instrumentation errors. The long-term stability of the transmitted signal (quartz oscillator control) was normally maintained within 2 parts in 10^{10} of its assigned value.

WWVL is also serving as an important experimental tool for studying the design problems of the 20-kc/s station to be built at Fort Collins. A closed-linked radio system—to phase lock the WWVL carrier to a standard frequency at Boulder—was designed, built, and tested. Results indicate that the phase of the 20-kc/s transmission can be held well within one microsecond of the USFS.

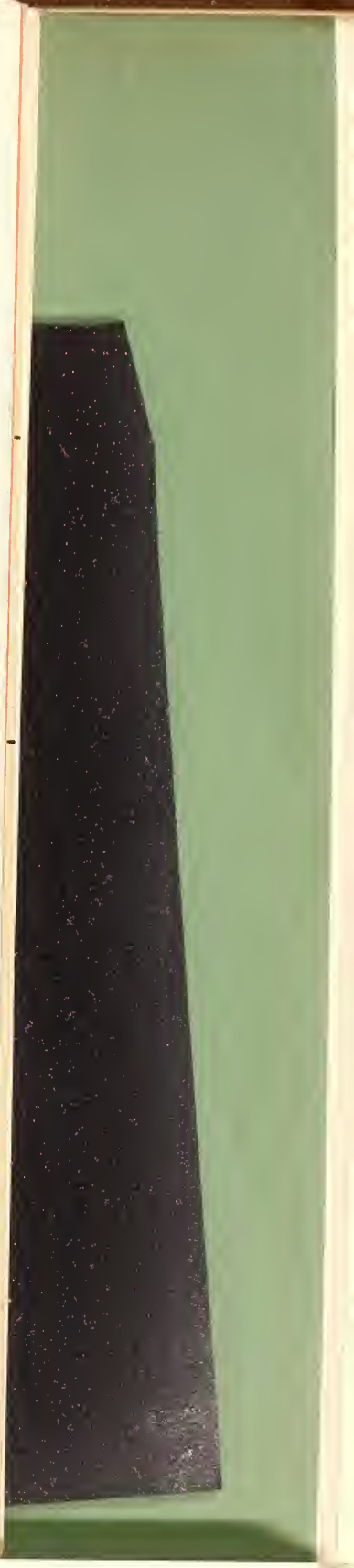
Initial steps were taken toward the establishment of an atomic time scale—capable of being synchronized or related to clocks at any remote location—by completing part of the redundant circuitry for supplying an unfailing frequency source referenced to the USFS.

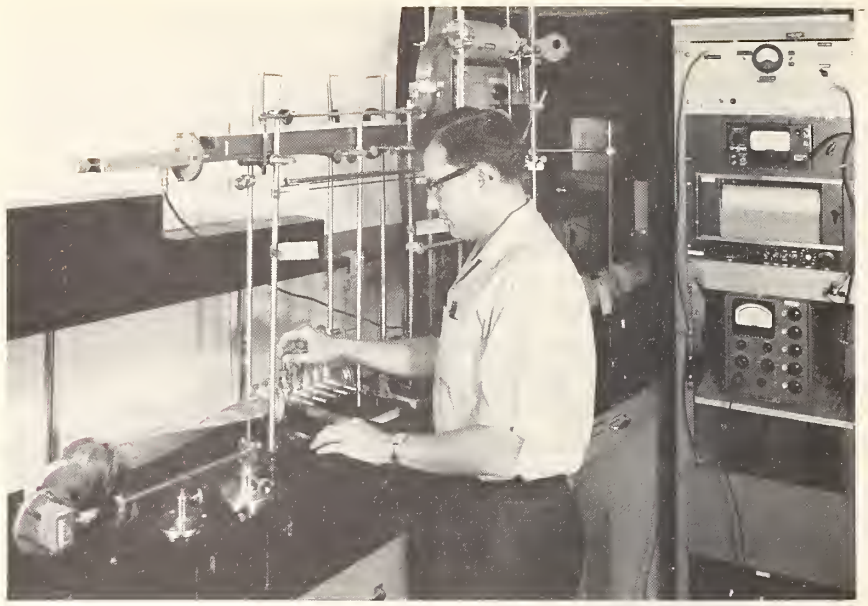
The accuracy of the WWV frequency transmission was increased by using measurement methods based on the LF and VLF transmissions. The maximum uncertainty is now 5 parts in 10^{11} Also, WWV began regular broadcasts of a timing code which gives the second, minute, hour, and day of year. This code is used to synchronize time generators at widely-scattered observation stations, and to automatically place time information on recorded telemetry signals from satellites and rockets.

High-Frequency Electrical Standards. In the high-frequency range, approximately 30 kc/s to 1,000 Mc/s, the emphasis and major achievements were in the fields of noise, power, and attenuation.

A comprehensive theory of a spectral density noise comparator was completed. This comparator, now under construction, should provide high stability, high sensitivity, and be capable of precisely measuring the ratio of noise sources over extremely wide ranges.

An experimental model of a stable, temperature-limited, thermionic-diode noise generator—with its plate current stabilized to the equivalent of 0.001 db





Reflectometer used to measure VSWR of coaxial components, extensively used in radio and telephone communication links. The instrument measures magnitudes of reflection coefficients to better than one percent (page 47).

of noise power—was developed, and construction was nearly completed on a permanent laboratory model.

A series of directional coupler power meters were developed and calibrated for the NBS Central Radio Propagation Laboratory. These were built for use at 40.92 Mc/s and 49.92 Mc/s at power levels of 300 kw cw and 1.5 megawatts peak pulse.

A directional coupler transfer standard was developed for international comparison at 300 Mc/s and an absolute power level of 100 milliwatts. Preliminary results from the initial comparison (with Great Britain) indicate agreement of better than 0.5 percent.

A coupler for 600-ohm balanced-line power measurements, with an accuracy of better than 10 percent, was developed and built for 4 to 60 Mc/s at 1 megawatt peak pulse power. The variations in repeated measurements of a calorimetric power standard, whose power range is from 0.05 to 5 watts, was reduced from 0.2 percent to less than 0.05 percent.

A sensitive detector, to be used for systems of precise attenuation measurement, is under design and construction. This will simultaneously indicate the direction of adjustment for both phase and magnitude controls in complex attenuation measuring systems.

When systems of attenuation measurement have sensitivities of 0.001 db or better, the stability of the various components can be very critical. To detect and evaluate instabilities a device was developed which has detected impedance changes in the order of 0.001 percent. It is also applicable to other quantities.

Microwave Circuit Standards. Measurements of the field strength and gain of microwave antennas are required to lay out radio and telephone communication links and to determine if radiation levels near the transmitters are hazardous to personnel. However, when measuring the gain of standard microwave horns in the laboratory, one problem has been that measurements of the antenna itself are complicated by multiple reflections from the walls and nearby objects.

During the past year substantial progress has been achieved in development of a technique which can discriminate between radiation from the horn and reflections from within the laboratory. This involves the generation of pulses which are only a few nanoseconds (a thousandth of a millionth of a second) in length, methods to detect the amplitude of these pulses to 0.01 db, and methods to discriminate against pulses arriving as little as 5 nanoseconds after the main pulse. The short pulses have been produced and a method to detect their amplitude to within a few hundredths of a db appears to be successful. Discrimination against the delayed pulses is presently limited to about 10 nanoseconds but a method of reducing this appears feasible and is being evaluated.

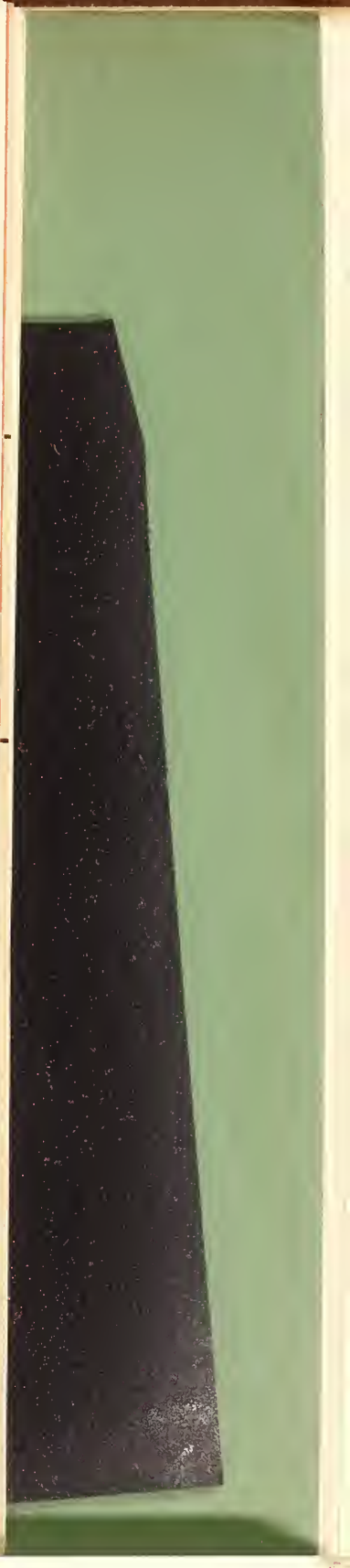
During the fall of 1960 three papers were published which specify the techniques required to measure microwave phase shift and which analyze the errors involved. This method is being adopted by various laboratories to establish a calibration service and also to measure phase shift in certain types of antennas.

A technique was developed, and the instrumentation completed, for a system to accurately measure VSWR of coaxial components at 4 Gc/s. This system is constructed entirely of rectangular waveguide except for the coaxial unit being measured and the uniform line to which this unit is attached. The instrument can measure magnitudes of reflection coefficients (over an intermediate range) to better than one percent.

The largest single source of error was eliminated in the NBS microwave radiometer. In the radiometer method of noise source comparison used at NBS the bandwidth is determined by a superheterodyne receiver. An inherent characteristic of such receivers is that they respond simultaneously to two discrete frequency intervals (signal and image channels). Heretofore the radiometer has been tuned for the median frequency between these two bands. A new technique, however, permits the radiometer to be tuned for optimum performance at the two frequencies simultaneously.

The impedance technique of measuring barreter mount efficiency has been refined to the point that calorimetric and impedance measurements agree within a few tenths of one percent. Since the two techniques are completely independent, the impedance technique provides a valuable cross check in microwave power measurements and it is also more easily adapted to the larger waveguide systems.

Thirty bolometer mounts were calibrated and turned over to the Electronic Calibration Center to support its calibration service. A new microcalorim-



eter was nearly completed which will extend the frequency range of the national standards to the region of 12.4 to 18.0 Gc/s.

Millimeter-Wave Research. The millimeter region of the electromagnetic spectrum—between wavelengths of about 3 mm and the long infrared—is virtually unused since these waves cannot be generated or detected with conventional electronic techniques. NBS research in this area is aimed at developing the special techniques and radio standards required to use these frequencies effectively.

New plates, used to contain the resonance region, were designed for the millimeter wave Fabry-Perot inteferometer. These consist of perforated films of silver deposited on glass and have resulted in better performance, easier adjustment, and easier fabrication. The interferometer has been used to measure the length of millimeter waves and has achieved accuracies of better than four-hundredths of one percent. In experiments with waves about 6 mm long the resonant cavity attained Q values of around 100,000.

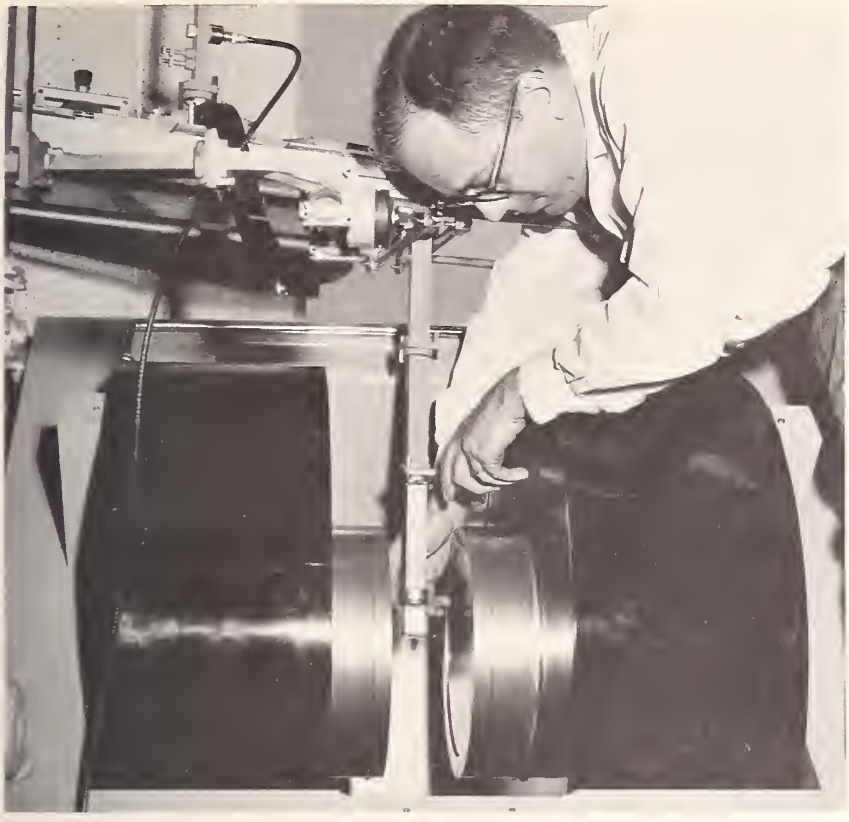
A theory and technique were developed for using the interferometer to measure dielectric constants and loss tangents of materials in sheet form. Measurements were made on plexiglass, polystyrene, and teflon with satisfactory results—the first such measurements known to be made in this region of the electromagnetic spectrum.

The perforated reflectors are not limited in shape and a reentrant biconical sphere was designed to test the spherical concept. This particular unit is four inches in diameter, and two sides of the sphere are perforated. Energy was focused at the center of the sphere, and it operated successfully at a wavelength of eight millimeters. This type of device shows great promise as a tuned resonant cavity for the generation of harmonic power at millimeter wavelengths. It offers a possible solution to the problem of designing a resonator, at these wavelengths, for two- and three-level solid-state masers.

A specific objective in this area is to make a redetermination of the speed of light, using a wavelength of 6.28 mm, and a millimeter wave Michelson-type interferometer operating in the Fresnel region of diffraction. A five-foot square aluminum reflector with precision carriage has been set up and most of the preliminary adjustments have been made. The refractometer is operable, and the instrumentation for the antenna pattern analysis is almost completely assembled.

Radio and Microwave Materials. Research in this area emphasizes the viewpoint of solid state physics in studying the interaction of electromagnetic waves and matter, particularly as this applies to the establishment and improvement of standards and measurement techniques. The prime interest is to acquire an understanding of the magnetic, dielectric, and conductive behavior of materials at radio and microwave frequencies in terms of the atomic constitution and structure of matter.

An important aspect of this work is the beginning of a materials measurement center to provide information on materials which is not readily available elsewhere. During the past year emphasis was upon the establishment of a group which is specifically concerned with studies of magnetic materials.



A waveguide cavity, containing a crystal specimen, is placed between the poles of a magnet in studies of magnetic resonance. The objective is the establishment of standards and measurement techniques, based on a better understanding of the interaction of electromagnetic waves with matter (page 48).

In the measurement of magnetization of materials a significant contribution was the development of an absolute technique for calibrating vibrating sample magnetometers. The new technique greatly improves the accuracy of determining spontaneous magnetization, a significant parameter in fundamental magnetic investigations, as well as a figure of merit in many microwave material engineering problems.

An improved Maxwell bridge was completed to measure resistance as low as 10^{-7} ohms, and inductance as low as 10^{-11} henrys, at frequencies from 1 to 100 kc/s. It is unique in that the sample of material can be inserted without opening the unknown arm of the bridge. Contact resistance is thus eliminated and low permeability measurements can be made with greater accuracy than previously possible.

A study of the dynamic magnetoelastic properties of several ferrites resulted in a new technique for analyzing the mechanisms responsible for magnetization in a material. This method is based on the fact that domain-rotation and domain-wall phenomena are apparently separated when magnetostrictive

measurements are made on selected ferrites subjected to mechanical shock. The dependence of Young's modulus on a static magnetic field was reported for the first time.

The accuracy of the rf permeameter was increased through the development of exact working equations. This has improved measurements on extremely low loss materials by at least an order of magnitude.

Magnetic resonance studies were initiated to determine the magnetic energy levels, relaxation times, and transition probabilities of paramagnetic and antiferromagnetic crystals. This will provide information on internal crystalline fields and exchange interaction. An investigation on the effect of impurities on the spontaneous magnetization of nickel was also instituted.

Electronic Calibration Center. The Electronic Calibration Center provides an extensive calibration service for various agencies in the Department of Defense as well as for scores of industrial laboratories. There is a continued effort to improve the instrumentation and thus increase the efficiency, accuracy, and scope of the Center's calibration services.

The method developed for the accurate calibration of inductive voltage dividers—using a transformer capacitance bridge—has surpassed all expectations of accuracy. By a conservative estimate, this method of measurement is accurate to within 0.2 parts per million of input. Calibration services for inductive voltage dividers were established for several values of ratio at an input voltage of 100 volts and a frequency of 100 c/s.

This year the Center had the opportunity to observe a group of saturated standard cells soon after the group had been measured by the NBS laboratories in Washington. Results indicate that agreement between the two laboratories is within 0.6 millionth of a volt, or well within the estimated limits of accuracy.

A modification of the rf voltmeter calibration consoles, which will improve their accuracy by a factor of 10 for frequencies up to 100 Mc/s, was nearly completed. These consoles cover the range of 30 kc/s to 100 Mc/s from 0.2 to 500 v, and the frequencies of 300 and 400 Mc/s from 0.2 to 100 v.

An attenuation calibration console which will permit very accurate measurement at 1, 10, 30, 60, 100, and 300 Mc/s was essentially completed. Its total dynamic range is 140 db, and it is estimated to be accurate within 0.07 db at the upper limit. Some of the more precise laboratory standards may be calibrated over a range of 0 to 60 db within an accuracy of $\pm$ (0.002 db + 0.01 percent of the total attenuation in db).

A technique, accurate to within one percent, was developed and services provided for the calibration of dry calorimeters for measurement of microwave power over a range of 10 to 100 milliwatts and a frequency range of 8.2 to 12.4 kilomegacycles.

A new high-temperature oven was designed and constructed, for the microwave noise measurement system, with a control circuit that maintains the temperature of the oven at a given point to 1 degree at approximately 1,000 °C. The hot-body noise standard was redesignated so that its operation is more reliable and its structure is easier to analyze.

2.1.5. 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 heat measurements. 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 National 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, in statistical thermodynamics, in high-temperature processes, in high-pressure thermodynamics, and in various aspects of plasma physics.

During the year significant progress was made in the generation and accurate measurement of high temperatures and pressures. An acoustical interferometric method was used successfully to measure very low absolute temperatures in the liquid helium range. The investigation of the thermodynamic properties of light-element substances important in rocket propulsion was continued. In addition, advances were made in long-range experimental and theoretical programs devoted to characterizing and predicting the properties of hot gases and highly ionized gases (plasmas).

High-Temperature Thermocouple Furnace. A tantalum-tube furnace has been designed and constructed to study the high-temperature properties of refractory metal and rare metal thermocouple materials. The furnace has been operated at temperatures up to 2,000 °C and, with minor modifications, temperatures up to 2,200 °C are anticipated. The heating element in the furnace is a tantalum tube heated through its own resistance. Thermocouples to be calibrated in the furnace are placed inside of the tantalum tube and are free from insulating and protection tubes. Blackbody temperatures at the measuring junctions of the thermocouples are determined by a calibrated commercial optical pyrometer with a modified optical system. Thermocouples can be calibrated in a high-purity helium atmosphere or a moderately high vacuum.

Electrical power to the furnace is regulated by a saturable core reactor. Stable furnace temperatures are maintained through the use of an automatic controlling unit which receives a feed-back voltage from the furnace transformer winding. At 1,500 °C the maximum temperature fluctuations indicated by a thermocouple over a 10-min period were less than 1 deg C. A limited amount of data have been obtained on tungsten-rhenium and iridium-iridium-rhodium type thermocouples. Other thermocouple combinations to be investigated include tungsten-tungsten 26 percent rhenium, tungsten-iridium, and tantalum-tungsten 26 percent rhenium (see p. 33).

Photoelectric Pyrometer. Above the freezing point of gold, 1,063 °C, the disappearing filament optical pyrometer is used for the realization of the International Practical Temperature Scale (IPTS). The precision of brightness temperature determinations with this instrument is limited by the

contrast sensitivity of the human eye. This limitation, however, can be reduced significantly by using a physical detector rather than the eye to make brightness matches.

During the past few years NBS has been developing a photoelectric optical pyrometer which uses a photomultiplier tube rather than the eye as a detector. This instrument, now completed, has a precision at 1,063 °C of 0.02 deg C when a time constant of 1 2/3 seconds and a target size of 0.2 mm by 0.6 mm are used. In comparison, the precision of the NBS visual optical pyrometer at 1,063 °C is about 0.3 deg C. Moreover, the higher precision of the photoelectric pyrometer has been achieved with a spectral passband of only 100 A, or about 1/4 that of the visual pyrometer. This is important because the mean effective wavelengths of the pyrometer can

As part of an effort to extend the range and accuracy of temperature measurements, the thermoelectric properties of high-temperature thermocouples such as tungsten-rhenium and tungsten-iridium are studied in this experimental tantalum tube furnace. Operating temperatures of 2,000 °C and higher are obtained (page 51).

be determined more accurately. The increased precision and the more accurate mean effective wavelengths are expected to improve the accuracy with which the IPTS can be realized.

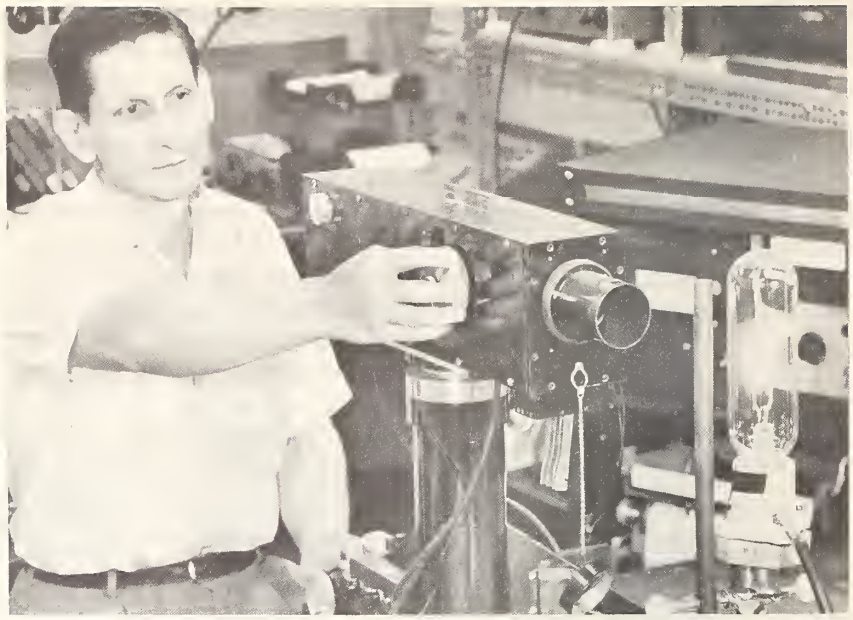
The long-term stability of the photoelectric pyrometer is now being investigated in order to determine how often the instrument will have to be calibrated. The heart of an optical pyrometer is the pyrometer lamp. This lamp serves as a reference standard for the pyrometer much as an electrical standard cell does for a potentiometer. Therefore, the stabilities of various types of pyrometer lamps are being determined. Preliminary results show that some lamps, previously considered excellent, change by an amount equivalent to 0.5 deg C in 150 hours of use at the gold point. These investigations are expected to result in recommended procedures for the optimum design, aging and use of pyrometer lamps.

Specific Heat of Diamond at High Temperatures. Accurate measurements of the specific heat of gem diamonds between 273 and 1,100 °K have recently been completed. These measurements will be used for comparison with values calculated theoretically from lattice dynamics over a wide temperature range. Such investigation should lead to a better understanding of the covalent bonds important to chemistry. It will also be possible to evaluate the energy contribution from nonharmonic vibrations in the diamond crystal. These assume greater importance with increasing temperature.

The high accuracy of this research will permit extrapolation of the measured specific-heat values to higher temperatures with less uncertainty than has been possible in the past. Other thermodynamic properties of diamond derived from this work permit examination of the temperature and pressure relationships which exist when diamond is formed from graphite.

Thermodynamic Properties of Light-Element Compounds. Under the sponsorship of the Department of Defense, the Bureau is continuing its comprehensive interdisciplinary program of thermodynamic research on simple light-element substances which are important in rocket propulsion. The compounds being specially investigated are those of lithium, beryllium, aluminum, and zirconium with hydrogen, oxygen, fluorine, and chlorine, as these compounds are potential fuel components, fuel oxidizers, and combustion products. During the past year the program extended its emphasis to include compounds of "mixed" type (such as intermetallic compounds, double fluorides of two metals, and oxyfluorides) whose use may lead to substantial gains in propulsion efficiency.

Though propulsion efficiency depends on the simultaneous operation of all the thermodynamic properties being separately investigated in the program, the most critical property is the heat of formation. The Bureau has recently contributed reliable values for this property for several important substances. A series of measurements established accurately the heats of formation of three alkali-metal perchlorates and ammonium perchlorate, the last substance in particular being a widely used fuel oxidizer. Nitronium perchlorate may have similar application, and measurements on it are under-



Photoelectric pyrometer, which eliminates the variability due to human error in strip lamp and optical pyrometer calibrations, has greatly increased the precision of temperature measurements above 1,063 °C. A phototube, rather than the human eye, is used to make brightness matches between the internal lamp and the source (page 51).

way. Another recent achievement was the successful development of a method for the complete combustion in a bomb calorimeter of a metal in fluorine when the product is relatively non-volatile. This work gave a heat of formation of aluminum fluoride which closely substantiates a value which had been determined by a less direct method, and raises this property to 15 percent above that accepted a few years ago. Similar measurements are being initiated to resolve a large discrepancy in the heat of formation of another important combustion product, beryllium fluoride.

The development and testing of new apparatus to measure other properties is nearing completion. In one of these, an exploding-wire device to study systems thermodynamically up to 6,000 °K and 100 atmospheres pressure, a major goal was achieved. The accuracy of measuring the total electrical energy entering an exploding wire during a few microseconds was verified when two independent types of comparison with the heat energy produced had an uncertainty of less than 2 percent. This agreement is considered very good for such short time intervals. The method of calibration employs a fixed resistance element as a calorimeter. The element is inserted in the discharge circuit in place of the exploding wire, and the calorimetric heating of the element is measured with high accuracy. This is used as a reference for comparing the ohmic heating and the electrical energy obtained from the measured current through the element and the measured voltage across the element.

A high-speed shutter has been developed in order to permit photographic observation of any portion of the electrical wire explosion. The shutter consists of two parts: a fast-opening part and a fast-closing part. Using Edgerton's method, the fast-closing action is obtained from the blackening of a window by exploding a series of parallel lead wires. The fast-opening of the shutter consists of a piece of aluminum foil (approximately 1 in. x 3 in.) placed directly in front of the camera lens so that no light may pass into the camera. The opening action is obtained when a capacitor, charged to high voltage, is suddenly discharged through the foil. During the discharge the magnetic forces set up by the passage of current cause the edges of the foil to roll inward toward its center line, thus allowing light to pass into the camera. Experiments have shown that the shutter is 75 percent open in about 60–80 microseconds. The shutter aperture may be made larger or smaller by changing the foil area and adjusting the electrical energy input to the foil.

Laboratory Measurements of Interstellar Radio Spectra. Besides the well-known hydrogen line at 21 cm wavelength, the spectra of extraterrestrial radio sources may contain sharp lines characteristic of other atoms, ions, and small molecules. The detection and study of such line spectra would add considerably to present information on interstellar gas clouds and, perhaps, planetary atmospheres. Among the most likely producers of detectable radio line spectra are the light diatomic hydrides OH and CH; somewhat less likely sources are the heavier hydrides SH, SiH, and ScH. Very small concentrations of these hydrides should be detectable; in interstellar gas, concentrations as low as 10^{-6} molecules/cm^3 may be sufficient, as compared to the 10^{-2} hydrogen atoms/cm^3 required for detection of the 21-cm line.

High sensitivity in radio telescopes is achieved by reducing the bandwidth of the receiver; therefore, only with precise foreknowledge of the line frequencies is an astronomical search for the radio spectra of these molecules feasible. To secure precise measurements of these frequencies, a research program in free radical microwave spectroscopy has been started. Since conventional methods are insensitive at the low frequencies of these molecular transitions, the paramagnetic resonance method is being used instead. This involves the application of a strong magnetic field to the radical vapor, which shifts the low-frequency spectra to a conveniently high microwave range, where they may be measured with optimum sensitivity.

The first diatomic hydride investigated by the paramagnetic resonance method was the OH radical. Results of this experiment include the frequencies of the two strong spectral lines by which OH may be identified in interstellar gas; the frequencies are 1665.32 and 1667.36 Mc/s, with an uncertainty of 0.10 Mc/s. Success in observing these spectral lines has so far, apparently, been confined to the laboratory; extraterrestrial observations have yet to be reported. Preparations are being made for similar experiments on CH and SH radicals.

Low Temperature Thermometry. The Bureau is pursuing an active program to provide a temperature scale and thermometer calibration services in the range 1.5 to 20 °K. The efforts and accomplishments fall into three main categories: absolute thermometry based upon the velocity of sound in helium gas, secondary thermometry involving principally studies of the behavior of germanium resistors, and helium-4 vapor-pressure measurements (see p. 144).

Acoustical Interferometer. An acoustical interferometer has been constructed and used, with helium gas as the thermometric fluid, to measure temperatures near 4.2 and 2.1 °K. Such an interferometer provides a means of absolute temperature measurement, and may be used as an alternative to the gas thermometer. When values of temperature derived with this instrument were compared with the accepted values associated with liquid helium-4 vapor pressures, differences of about 10 and 7 millidegrees respectively were found. This result is preliminary, and work is continuing.

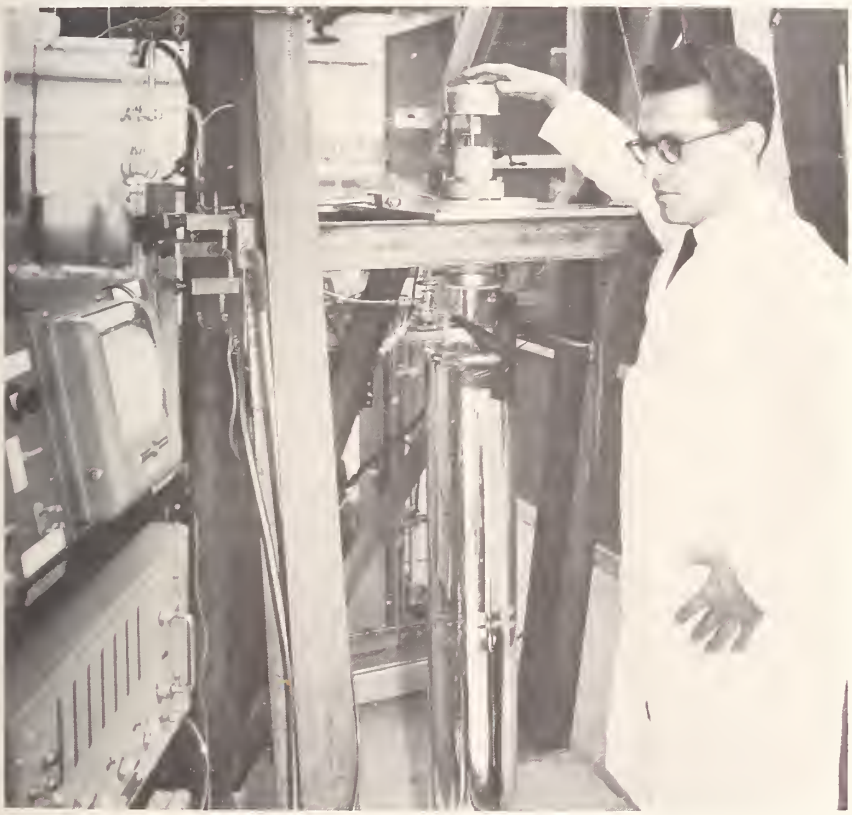
Resistance Thermometers. Carbon resistors and impurity-doped germanium resistors have been investigated for use as precision secondary thermometers in the liquid helium temperature region. Several germanium resistors have been thermally cycled from 300 to 4.2 °K and their resistances have been found to be reproducible within ⅓ millidegree when temperatures were derived from a vapor pressure thermometer whose tubing is jacketed through most of the liquid helium. Preliminary calibrations of the resistors have been made from 4.21 to 2.16 °K at every 0.1 °K. The estimated standard deviations of the data for two of the resistors were $\leqq$ 1 millidegree; and for the third resistor, $\leqq$ 3.3 millidegrees.

Vapor Pressure Method. The reproducibilities of helium vapor-pressure thermometers have been investigated in conjunction with a "constant temperature" liquid helium bath from 4.2 to 1.8 °K. Surface temperature gradients have been found to exist in liquid helium baths contained in 15- and 25-liter metallic storage dewars. The gradient was about one half of a millidegree at 4.2 °K but increased to several millidegrees for bath temperatures slightly greater than the λ point. A hydrostatic head correction has been neither necessary nor applicable in the determination of vapor pressures or temperatures for the bulk liquid helium. However, the surface temperature gradient can produce erroneous vapor-pressure measurements for the bulk liquid helium unless precautions are taken to isolate the tube (which passes through the surface to the vapor pressure bulb) from the liquid helium surface. It has also been observed, in helium II, that large discrepancies can exist between surface vapor pressures and those pressures measured by a vapor pressure thermometer. This has been attributed to helium film flow in the vapor pressure thermometer. In this case also the design of the thermometer can be modified to reduce the helium film flow.

Pressure Transducer for PVT Measurements. Precise pressure-volume-temperature measurements on corrosive gases are dependent on a sensitive yet rugged pressure transducer. A prototype which fulfills the requirements was developed and thoroughly tested. The transducer is a null-

type instrument and employs a stretched diaphragm, 0.001 in. thick and 1 in. in diameter. A small pressure unbalance displaces the diaphragm and changes the capacitance between the diaphragm and an electrically insulated plate spaced 0.001 in. apart (for $\Delta P = 10$ microns of mercury, the average displacement $= 10^{-6}$ in. and $\Delta C = 0.014$ pf). Spherical concave backing surfaces support the diaphragm when excessive pressures are applied and prevent the stresses within the diaphragm from exceeding the elastic limit. Over a temperature range from 25 to 200 °C and at pressures up to 250 atm, an overload of 300 psi, applied for a period of one day, results in an uncertainty in the pressure of, at most, one millimeter of mercury.

Transport Properties of Air. A 6-year study of the transport properties of air at elevated temperatures has been completed. This project was carried out under sponsorship of the Ballistic Missile Division of the Air Research and Development Command, U.S. Air Force, and had as its goal the investigation of the transport by diffusion of the heat energy of chemical binding. A significant effect discovered during the study is the existence of Prandtl numbers reaching values of more than unity in the nitrogen dis-



Absolute temperature measurement in terms of the speed of sound in helium gas at liquid helium temperatures is one phase of the program to provide a temperature scale and thermometer calibrations in the range 1.5 to 20 °K (page 56).

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sociation region. Another effect discovered is the large coefficient of thermal diffusion tending to separate nitrogen from the oxygen when temperature differences straddling the nitrogen dissociation region are present. The results of the study, based on collision integrals computed from the latest critically evaluated data on intermolecular forces in air, will be reported in the form of a table of viscosity, thermal conductivity, thermal diffusion, and diffusion coefficients at temperatures of 1,000 to 10,000 °K and of logarithm of pressure in atmospheres from 10^{-8} to 10^{3} times normal density.

International Cooperative Activities. In March, 1961, representatives of the national laboratories of Australia, Canada, The Netherlands, United Kingdom, U.S.S.R., United States, and West Germany, met at the NBS to devise means for reaching international agreement on a temperature scale between 10 and 90 °K. As a first step toward this goal, arrangements were worked out for comparing the scales now in use through circulation of a group of standard platinum resistance thermometers for calibration by each national laboratory. Such a group of thermometers was obtained and calibrated at the NBS. These thermometers have now been sent to the United Kingdom for calibration at the National Physical Laboratory.

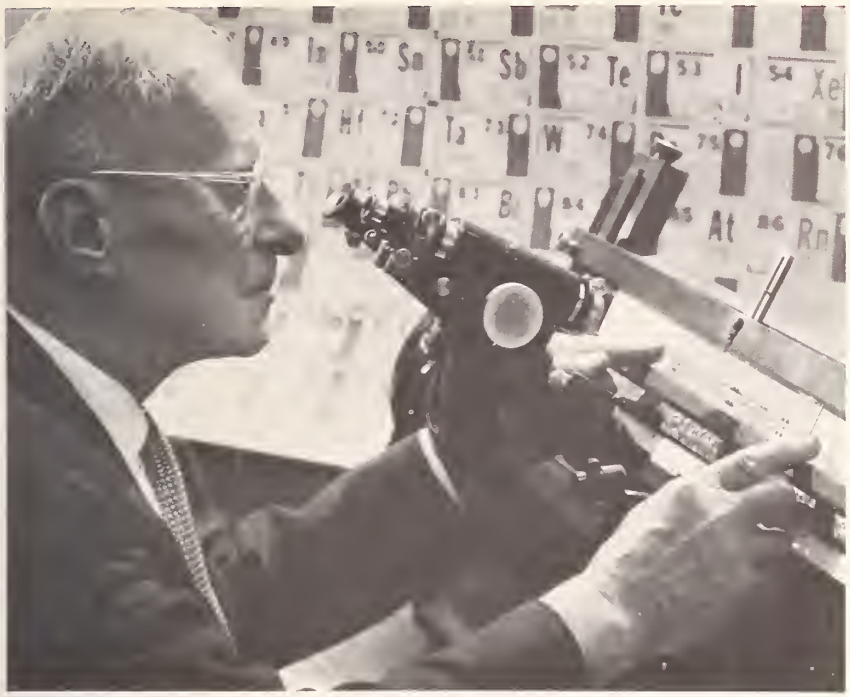
Temperature Symposium. During the last week of March 1961, Columbus, Ohio was the site of the Fourth Symposium on Temperature, Its Measurement and Control in Science and Industry. The Symposium, which was jointly sponsored by the American Institute of Physics, the Instrument Society of America, and the National Bureau of Standards, attracted nearly one thousand registrants, including many from abroad. The Bureau contributed to the planning and success of the Symposium through the efforts of Mr. W. A. Wildhack, General Chairman, and Dr. C. M. Herzfeld, Program Chairman. Dr. A. V. Astin, NBS Director, opened the 5-day session with introductory remarks, following which a total of twenty-six papers were given throughout the week by NBS scientists, from both the Washington and Boulder Laboratories.

2.1.6. ATOMIC PHYSICS

In addition to the basic programs in wavelength standards, spectroscopy, solid state physics, interactions of the free electron and atomic constants which are necessary to provide the foundation for technological progress, the Bureau has strengthened its activities in laboratory astrophysics. The programs in infrared spectroscopy are undergoing reorientation toward wavelength standards in the far infrared, the application of infrared techniques to solid state studies, and increased emphasis on high resolution instrumentation. Two data centers have been established for the collection, indexing, critical evaluation, and dissemination of bibliographies and critical values in the fields of transition probabilities and collision cross sections.

Laboratory Astrophysics.

Transition Probabilities. Under the sponsorship of the Office of Naval Research and the Advanced Research Projects Agency, a data center was



The spectral intensities of over 39,000 lines for 70 elements were determined and published in tabular form. The new tables provide spectrochemists with much-needed quantitative intensity values for those elements most commonly encountered in their analyses (page 59).

established to gather and index all published information on atomic transition probabilities. An exhaustive survey was made of the literature, and a primary reference file of approximately 600 references was catalogued. Selected bibliographies and tables of available data are now in preparation.

A wall-stabilized high-current arc source was constructed and used to study transition probabilities of atomic hydrogen and oxygen. This apparatus will also be used to measure transition probabilities of a large number of other elements. A study of the hydrogen line profiles indicates that a measurement of these profiles can be used to calculate a temperature for the arc plasma that is reliable to about ± 2 percent.

A set of tables containing spectral intensities for 39,000 lines of 70 elements, as observed in a copper matrix in a d-c arc, was completed and published. Studies of the intensity data indicate that they may be converted to approximate transition probabilities. These data are not of the precision obtainable by the methods previously mentioned, but the vast number of approximate values available will be useful in many areas.

Atomic Energy Levels. Research continues on the very complex spectra of the rare earth elements. New computer and automation techniques were applied to these spectra with considerable success. A number of energy levels were found in the spectrum of cerium; none had previously

been known in this spectrum. Substantial progress was made in the analyses of the spectra of thorium, praseodymium, ytterbium, bromine, and dysprosium.

The work on spectrum analysis has been aided greatly by theoretical prediction of the positions of energy levels in low, even configurations. Extensive computations were made on the first spectra of hafnium and tantalum and the third spectrum of praseodymium.

Collision Cross Sections. The measurement and calculation of low-energy collision cross sections was continued, with efforts concentrated on construction of apparatus and refinement of instrumentation. Special emphasis is being given to the development of sources of low-energy monoenergetic electron beams for use in measurement of elastic and inelastic collision cross sections.

Theoretical studies of the use of refined wave functions in the calculation of electron scattering and photodetachment are continuing. Several high-vacuum instruments for measuring electron collision cross sections are essentially completed.

The photodetachment of electrons from carbon negative ions was observed and studied. Careful measurements of detachment near threshold for the process lead to a value for the electron affinity of carbon of $1.25 \pm .03$ ev (28.6 kcal). Values of upper limits for the photodetachment cross sections of several of the important atmospheric negative ions were determined at a wavelength of 4000 A.

Studies involving very precise measurements of the dependence of drift velocities of argon ions in the parent gas on the electric field have been completed. The results raise serious doubts concerning the validity of current theory describing the motions of charged particles in gases.

A data center was established to gather and index all published information on collision cross sections. A complete file of reprints of papers on low-energy electron cross sections was collected. A code has been worked out for tabulating the large number (over 800) of references on punch cards. About one-half the papers have been coded. The data collection will be extended to cover other atomic cross sections.

Standard Wavelengths. The wavelength of the resonant line emitted by an atomic beam of mercury 198 was measured relative to the standard wavelength emitted by the krypton-86 isotope, which was adopted in 1960 as the new international standard of length. The line emitted by the mercury-198 beam is nearly ten times as sharp as the krypton standard line.

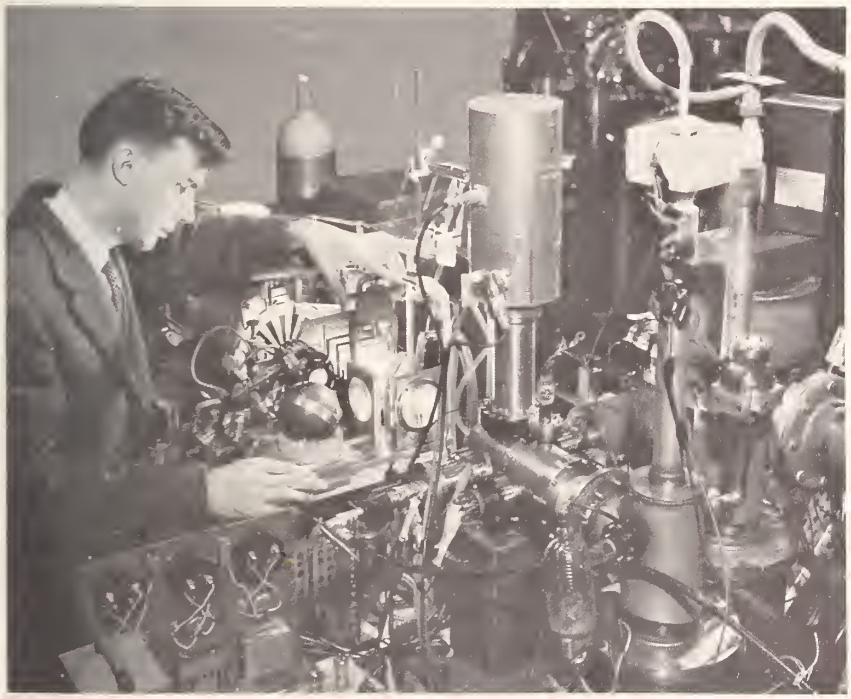
Several atomic beam devices are under development that show promise of producing wavelength standards potentially superior to the present international standard (see 2.1.1., p. 21).

Infrared Spectroscopy of Gases. During the past year a great deal of materials research was conducted on the infrared spectra and vibration-rotation energy levels of various compounds. This research was sponsored

by the Atomic Energy Commission. Work was completed on the analysis of the infrared spectrum of acetylene. In this work, the values of a number of vibrational and rotational constants for C_2H_2 were very accurately established. Similar studies on the deuterated acetylenes, C_2HD and C_2D_2, were initiated. When the constants for all three of these molecules have been obtained, it will be possible to arrive at very accurate values for the bond lengths and other structural parameters for acetylene. This work is of great importance as it offers the best way of obtaining these parameters for a compound which is considered by chemists to be a classic example of a triple carbon-carbon bond.

Infrared Spectroscopy of Solids. Work has been initiated on fundamental studies of the infrared spectra of solids and the effects of crystal structure, temperature, and purity on these spectra. Because of the complexity of the problem and of the state of knowledge of intermolecular forces and the manner in which they affect the infrared spectra of solids, much fundamental work is needed in this field. A study of CO has shown that because of interactions between neighboring molecules in the solid, the absorption frequency of the most abundant isotopic species is shifted slightly, while that of the isotopic species present in smaller abundance is unaffected.

Solid-State Physics. Pure rutile (TiO_2), has a large, low-frequency dielectric constant ($\epsilon_c = 173$ and $\epsilon_a = 89$ at room temperature). The Bureau's



Studies of the photodetachment of electrons from negative atomic and molecular ions provide a better understanding of the ionized layers of the upper atmosphere (page 60).

work reconfirmed these values and explained disparities in previously published data. Because of the close relation between rutile and several ferroelectric titanates, the temperature dependence of the dielectric constant was studied between 1.6 and 1,060 °K. In both the *c*- and *a*-directions, the dielectric constant changes only by a factor of 2 or 3 and no anomalies occur. Lorentz corrections, polarizabilities, and effective charges were calculated. It appears that the polarizabilities in rutile are within 10 percent of the critical values for the ferroelectric catastrophe over the entire temperature range.

A considerable amount of data was taken on the electrical, magnetic, and optical properties of rutile. There is now strong evidence that one of the major defects in reduced rutile is an interstitial Ti-ion.

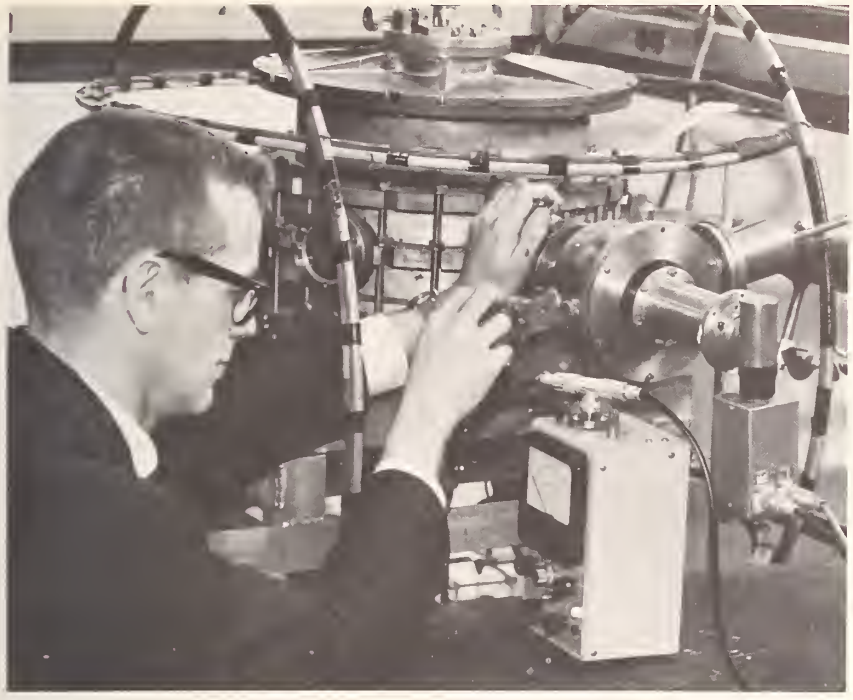
Titanium sesquioxide with excess oxygen has been shown to be a *p*-type semiconductor below the transition point at 480 °K, while the conduction is metallic in character above that temperature.

A theoretical study was made of the electrical conductivity, Hall coefficient, and thermoelectric power of decomposing oxides as a function of the oxygen vapor pressure at high temperatures. As a result of this analysis, methods were selected to derive intrinsic parameters such as energy gap and effective masses from measurements of the pressure dependence of the transport properties.

Investigations of electron spin resonance absorption in oxides were initiated in collaboration with the mineral products laboratory (see p. 84).

Electron Scattering. A single scattering experiment tied together three previously unrelated topics (diffraction, characteristic-loss scattering, and plural scattering theory) and provided new insight into the theoretical model of electron scattering in solids. The measurements represent the first detailed experimental example of a theory of electron scattering proposed in 1921 by Wentzel, and support a model of inelastic scattering proposed by U. Fano of NBS in 1956. They show that electrons elastically scattering from aluminum foils have the same angular distribution for all foil thicknesses, indicating that the elastic scattering process is a type of diffraction. Moreover, the inelastically scattered electrons undergo repeated collisions of a type involving long-range interactions with the electrons of the target material.

Culminating several years of research effort, the first time-resolved photographs of a pulsed cadmium atomic beam (density $\sim 10^{11}$ particles/cm^3, equivalent to $\sim 10^{-5}$ mm Hg pressure) was achieved by means of an electron-optical stroboscopic method. The purpose of this work, which is sponsored by the Office of Naval Research, is to develop a method to measure the vector-velocity distributions of gas molecules reflected from solid surfaces and to use these data to compute the coefficients of thermal accommodation and viscous slip. Low-density collimated pulses of gas atoms (or molecules), moving rectilinearly in a narrow velocity range (around 300 m/sec), are photographed by an electron optical schlieren technique. The electron



An electron scattering experiment, utilizing an improved electron filter lens, provided new insight into the theoretical model of electron scattering in solids (page 62).

beam is pulsed stroboscopically, thus providing a picture of the instantaneous distribution of atoms at a known time after the formation of the atomic beam pulse. The time delay between the atomic beam pulse and the electron beam pulse is varied so that the velocity distribution in the atomic beam may be studied.

Atomic Constants. Plans were developed and equipment is being assembled for a new precision measurement of the cyclotron frequency of the electron. This experiment will provide a sensitive check on the predictions of quantum electrodynamics concerning the anomalous magnetic moment of the electron.

Atomic Standards of Frequency. The construction of several prototype frequency standards based on hyperfine resonances in rubidium vapor was completed, and the performance of the standards is being evaluated by systematically intercomparing them with the primary standards at the Bureau's Boulder Laboratories. Plans to use a miniaturized version of the clock for a test of relativity theory were discontinued as a result of measurements made elsewhere using the newly discovered Mossbauer effect.

A rubidium vapor maser with an oscillation parameter of about 0.6 was developed. Further improvements being attempted at Columbia University are expected to achieve unity oscillation.

2.1.7. RADIATION PHYSICS

The increasing application of atomic and nuclear technology to industrial, medical, and defense activities has resulted in an expansion of the demands placed upon radiation research. Industrial uses of radiation have brought about a growing need for improved standards and dosimetry at high dose levels and high energies. Medical users increasingly turn to higher energies and call for improved determination of both source output and absorbed dose. Research workers interested in the effects of radiation on various materials have need for more information in their field. The Bureau has attempted to meet these increasing demands with its radiation research program.

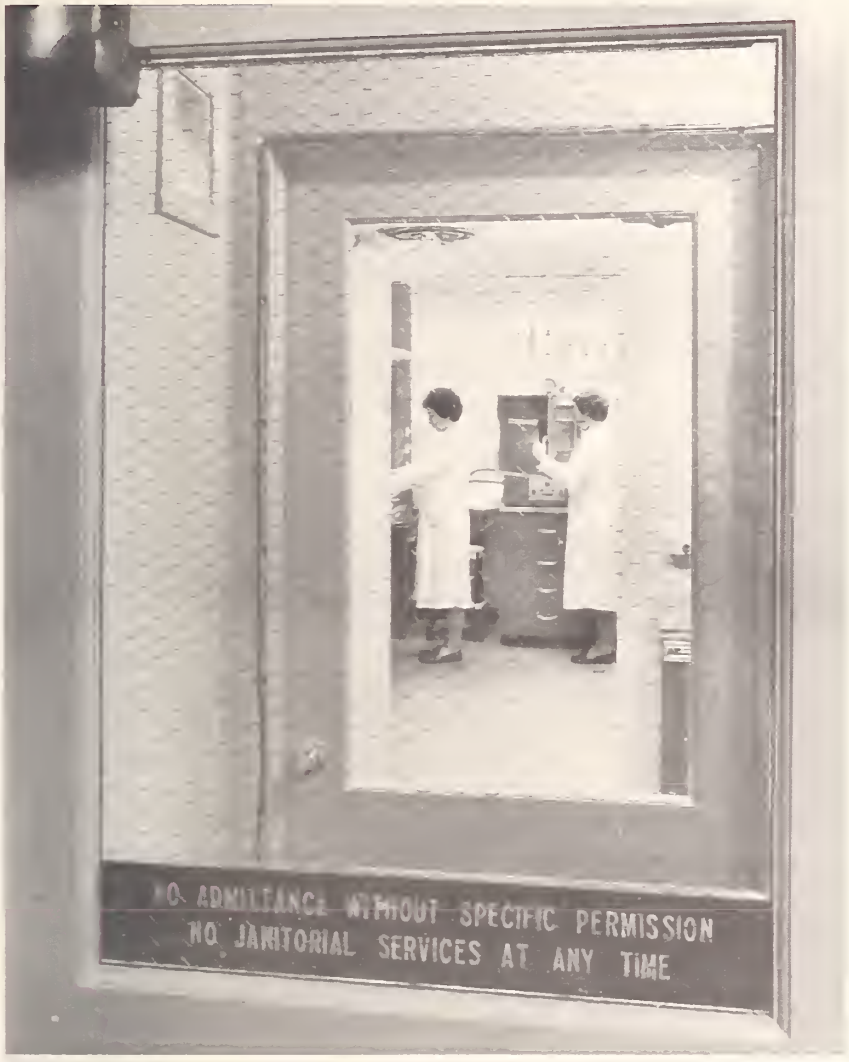
The research of the Bureau is directed toward obtaining basic experimental and theoretical data concerning the interactions of radiation with nuclei, atoms, and molecules, as well as with bulk matter; the investigation, development, and improvement of radiation sources and standards; and the development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

Radioactivity Standards. A manganese 54 point-source standard, a scandium 46 gamma-ray solution standard, an iron 55 electron-capturing nuclide standard, and a promethium 147 beta-ray standard were developed during the year. Using the NBS internal compensated gas counters, the half-life of carbon 14 has been redetermined as $5{,}760 \pm 50$ years, where the indicated uncertainty denotes an estimated overall probable error of the result.

The low-level counting facilities have been completed and the "white" room which was designed to exclude 99.9 percent of all dust particles greater in size than 1 micron has so far revealed none larger than 0.1 micron. This facility is for studying methods of measuring the amounts of radionuclides present at very low concentrations and in making international intercomparisons of radioactive samples at these concentrations. The program has also included an examination of low levels of contamination of materials and reagent chemicals by any radionuclide.

Radiation Theory. To provide information on the basic processes of radiation production, on the characteristics of the radiations, and on their absorption by, or other interactions with, matter the Bureau maintains a broad program in radiation theory. Work on photon and neutron penetration, together with application to structure shielding against radiations from nuclear weapons, has been partially supported by the Office of Civil and Defense Mobilization and the Defense Atomic Support Agency. Work on charged particle penetration and elementary cross sections has been partially supported by the Office of Naval Research.

Computer Programs. Major and sophisticated computer programs have been developed for calculations of electron and gamma-ray penetration. The Monte Carlo program of calculating the multiple scattering of charged particles has been so refined that it is now possible to analyze the differences



"White" room constructed for use as a low-level radioactivity laboratory and a sample-preparation room. This facility is used in studying methods for measuring very low concentrations of radionuclides and for international comparisons of radioactive samples at these concentrations (page 64).

between electrons and positrons in regard to phenomena such as backscattering or transmission by thick foils. The Monte Carlo program has also been applied to the analysis of proton range and stopping power experiments, with the aim of extracting the best value of the "mean excitation potential," which is a key parameter in the stopping power formula. A program for calculating neutron penetration distributions by moment methods has been nearly completed. This program should make it possible to study the physics of neutron penetration in detail. and should also make possible a much wider variety of deep penetration data than has ever been available before. Exploratory applications of this program are underway.

A nuclear optical model code was written to predict neutron elastic scattering cross sections. This code includes an estimate of the compound elastic scattering in addition to the shape elastic scattering which comes directly from the nuclear optical model. A report was prepared on the elastic scattering cross sections for calcium.

Data Collection. Data collection activity during the past year included a tabulation of X-ray spectra in uniformly contaminated media. This tabulation was also used for a detailed analysis of the errors that arise in the numerical solution of the X-ray degradation equation.

Results of the proton Monte Carlo work at 340 Mev and 660 Mev on range and range straggling has been analyzed and an estimate has been obtained of the small systematic error resulting from the particular Monte Carlo model that has been used. The sampled data was also used to obtain an estimate of the statistical distribution of the difference between path-length and depth of penetration for high-energy protons.

Civil-Defense Shielding Problems. Considerable work has been done toward the theoretical solution of shielding problems associated with the "fallout" of fission products from nuclear explosions. A monograph, "Structure Shielding Against Fallout Radiation from Nuclear Weapons," has been virtually completed. Work has been started to develop engineering data applicable to initial radiations, in analogy to the work completed for fallout radiations. Some work on Monte Carlo calculations for the analysis of simple structure geometries has continued but the emphasis has shifted to more complex geometries than slabs. The computer programs for calculating gamma-ray penetration have been revised and made more general, in order to make possible their use by other investigators; their use to produce more detailed information about flux angular distributions; and to make possible reliable calculations at high energies (<10 Mev).

Linear Electron Accelerator. The Bureau has been engaged for some time in the design of a new linear electron accelerator to be housed in its new Gaithersburg facility. This accelerator will produce a 100-Mev electron beam with 40 kilowatts in the beam. The design of the accelerator has been completed and the machine is now under construction. It is expected to be completed in November 1962. During the past year considerable effort has been devoted to completing the design of the laboratory in which the accelerator will be housed and the design of a beam-handling and analysis system. Since the accelerator will provide a beam with an energy spread of less than 2 percent, it will be possible to utilize a large fraction of the electron beam even after energy analysis by the beam-handling and analysis system of magnets, which will provide energy resolutions as small as 0.05 percent.

The magneto-optical properties of systems of magnets were studied during the course of the design of the linac beam-handling system. A convenient matrix method was developed and applied to combine by a first-order procedure analyzing and quadrupole magnets in order to predict the focusing and dispersing properties of combinations of magnets. This method

has now been published in a paper that demonstrates the general applicability of the matrix techniques to general deflection magnets. The method has also been used to predict by a second-order theory the properties of precision particle spectrometers. It has now been demonstrated that an energy resolution better than 0.05 percent is obtainable for reasonable target sizes with particles having momenta up to 250 Mev/C and with solid angles in the range from 0.005 to 0.01 steradians.

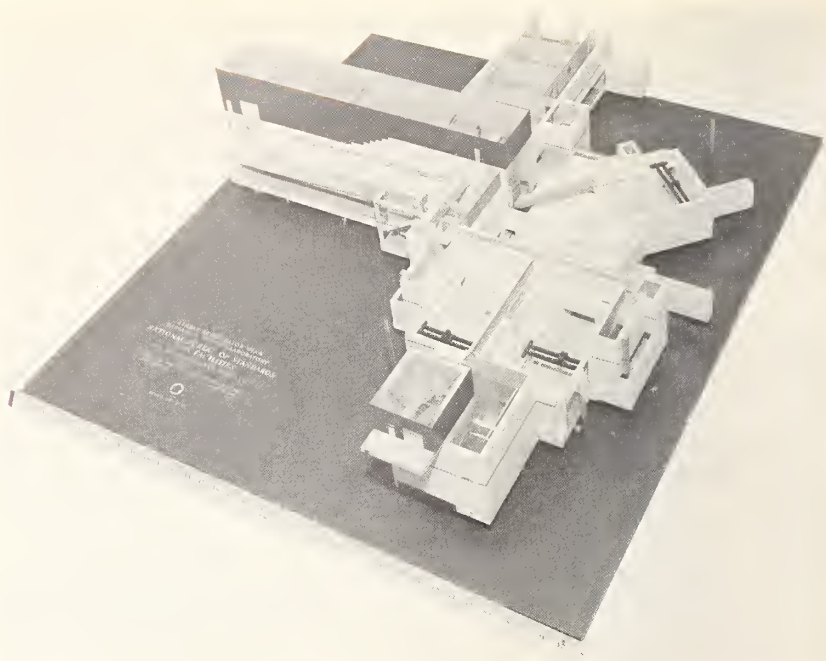
High-Energy Radiation. Research utilizing the betatron and synchrotron included two studies partially supported by the Atomic Energy Commission. One of these dealt with the measurement of neutral meson production for carbon, aluminum, copper. cadmium, and lead. The other involved a measurement of the photoneutron yield and photon-scattering cross sections for the highly deformed nuclei of holmium and erbium.

Angular distributions of neutral mesons photoproduced by 170 Mev bremsstrahlung from the synchrotron have been measured. The experimental distributions have been compared to Monte Carlo predictions and thereby have provided a measurement of the root mean square radii of nucleon center distributions having an estimated uncertainty of three percent. These results are about 0.2 fermi lower than the electron scattering measurements of the rms radii of charge distributions obtained at Stanford University. About one-half of this difference is understandable on the basis of the proton size. The remaining difference is approximately equal to the present uncertainties in the experiment and, therefore, may or may not be real.

The observed X-ray scattering cross sections for holmium and erbium were large compared to those calculated from the observed absorption (photoneutron) cross sections by means of the optical theorem and the dispersion relations. The absorption and scattering cross section are consistent if it is assumed that these nuclei have a large intrinsic tensor polarizability. The data also suggest that in the energy region between 10 and 23 Mev as much as 10 to 20 percent of the integrated absorption cross section is not associated with the tensor polarizability.

A third nuclear physics program that was actively investigated during the past year was the measurement of total nuclear cross sections. This work has required the development and improvement of the energy resolution of high-energy scintillation X-ray spectrometers. The best results were provided by a sodium-iodide spectrometer with a resolution of 2.5 percent at 17.6 Mev.

Total nuclear absorption cross sections are being measured with this spectrometer by examining the X-ray spectrum of 90 Mev bremsstrahlung transmitted by long absorbers in a good-geometry experiment. The use of the spectrometer combined with the high-intensity NBS synchrotron beam made it possible to attenuate the primary X-rays by a factor of over 10,000 with a resulting enhancement in the transmitted spectrum of the effect of small changes in the attenuation coefficient. The transmitted spectra show clearly the giant resonance nuclear cross section, as well as fine structure



Model of the linear electron accelerator complex which will be built as part of the NBS Radiation Physics Laboratory at Gaithersburg, Maryland. Dotted line on the model indicates the ground level (page 66).

in such absorbers as oxygen, carbon, and magnesium. The detailed evaluation of the total nuclear and the total interaction cross sections in a wide range of elements will be completed at the end of the present series of experiments.

X- and Gamma-Ray Dosimetry. It is often assumed that cobalt 60 beams used for instrument calibration and radiation treatment contain only gamma rays with energies of 1.17 and 1.33 Mev. Though it is widely recognized that this assumption is not strictly valid because of the energy degradation due to scattering, adequate experimental data was not previously available to show the magnitude of the discrepancy. Therefore, experiments were conducted to determine the intensity and energy of scattered radiation from multicurie cobalt 60 sources and its variation with source and collimator geometry.

Photographic Dosimetry. The Bureau has investigated the effects of exposure of X-ray film to two successive types of radiation. The results of this study show that the shapes of the density-versus-exposure curves resulting from such dual exposures are essentially the same as those of the curves resulting from the second exposure alone. This work, supported by the Atomic Energy Commission, may lead to a better understanding of the nature of the photographic latent image and may also be of some interest in industrial and military applications of photographic dosimetry of X- and gamma-radiation.

A simple film method of measuring X- and gamma-ray exposure doses in the megaroentgen range has been developed at the Bureau with the support of the Atomic Energy Commission. The method extends the exposure range of commercial photographic film to 10^8 roentgens by employing a special densitometric procedure. Since the print-out effect is utilized, no photographic processing of the film is required. A preliminary study has been performed on extending the method to exposures lower than 10,000 roentgens by a chemical treatment of the films prior to exposure. Results obtained with one film type pre-treated with a ten-percent solution of sodium sulfite showed some promise.

Chemical Dosimetry. An investigation has been made of the spectrophotometric method of measuring the ferric ion yield in the ferrous sulfate dosimeter. The ferric ion yield produced by ionizing radiation in a ferrous sulfate dosimeter is usually determined by measuring the absorbance (optical density) of the irradiated solution at a wavelength of 304 millimicrons. By measuring the ferric ion yield at 224 mμ, instead of at 304 mμ, the sensitivity of the spectrophotometric method can be approximately doubled and the measuring range of the ferrous sulfate dosimeter using this method can be extended to lower doses. The molar extinction coefficient at 224 mμ is much less temperature dependent that at 304 mμ, and shows also a smaller dependence on sulfuric acid concentration than at 304 mμ. Values of the ferric ion yield produced by Co^{60} gamma rays determined by measuring the absorbance at 224 mμ and 304 mμ agreed within experimental errors.

Irradiation Facilities. Through the cooperation of the Atomic Energy Commission, a 50,000-curie high specific activity cobalt 60 source has been obtained and installed at the bottom of a 12-foot-deep water pool. This source gives a gamma-ray field of more than 10^7 roentgens per hour, thus shortening required exposure times by a factor of about 25 over that for the Bureau's 2,000 curie source. The new source will be utilized in dosimetric studies involving high intensities, studies of the effects of intense gamma radiation on various fluorocarbons, studies of gamma-ray production of radicals at low temperature, and in an investigation of the relationship between radiolysis and photolysis.

Nucleonic Instrumentation. In a program supported by the Atomic Energy Commission a new type of pulse-height analyzer was developed and placed in operation, in conjunction with the NBS 180-Mev synchrotron This analyzer, designated as a "charge-storage analyzer" since it uses temporary electrostatic charge storage, is designed for use with pulsed accelerators. Efficient operation of pulsed accelerators necessitates the analysis of many pulses during the bursts of radiation. This often involves dealing with pulses separated in time by only a few microseconds and is accomplished with this analyzer by temporarily storing the pulse-height information on the face of a cathode-ray tube, followed by analysis of this stored data during the relatively long dead intervals between bursts. This instrument is currently being used in nuclear absorption experiments that would be extremely difficult to perform with conventional analyzers.

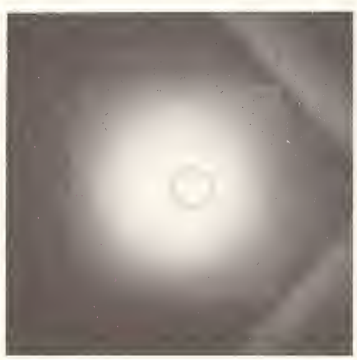
Neutron Physics. In research supported by the Atomic Energy Commission and the Defense Atomic Support Agency, the Bureau is conducting fundamental experiments on neutron penetration and neutron cross-sections. This research provides information important for the protection of personnel, for investigation of the interaction of radiation with materials, and for understanding nuclear structure.

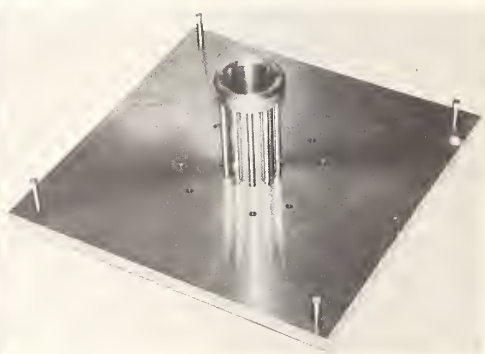
During the year a precision long counter was constructed, calibrated, and compared with a similar instrument built at Hanford, Washington. Agreement to within one percent was obtained.

The emission rate of the NBS standard neutron source (NBS-I) is being redetermined by comparison with an antimony-beryllium neutron source in an absolutely calibrated heavy-water manganous sulfate bath.

Measurements of elastic and inelastic scattering of 14 Mev neutrons by time-of-flight from Ca^{40} and C^{12} were made. The results yield the ratio of elastic to inelastic scattering and show an angular distribution of elastic scattering in agreement with theory.

Radiation Protection and Radiation Standards and Units. Research on the fundamental properties of radiation and on radiation standards has placed the Bureau in a unique position to translate the latest information in these fields into practical recommendations for radiation protection, quantities and units. The Bureau has assisted in the dissemination of this information by publishing as NBS handbooks the recommendations of the National Committee on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Units and Measurements (ICRU). During the last year, five new handbooks have been published. These include: Handbook 72, "Measurement of Neutron Flux and Spectra for Physical and Biological Applications"; Handbook 73, "Protection Against Radiations from Sealed Gamma Sources"; Handbook 75, "Measurement of Absorbed Dose of Neutrons, and of Mixtures of Neutrons and Gamma





The Bureau's new 50,000-curie cobalt-60 source at the bottom of a 12-ft water shielding pool, pictured with light from its own Cerenkov glow. The largest single isotope source ever shipped by the AEC's Oak Ridge National Laboratory, the new source greatly extends NBS capabilities in radiation calibration and the investigation of the effects of radiation on the properties of materials. At right, the geometry of the 50,000-curie source; the Co^{60} is contained in the vertical metal tubes at the center (page 69).

Rays"; Handbook 76, "Medical X-ray Protection up to 3 Mev"; and Handbook 78, "Report of the International Commission on Radiological Units and Measurements (ICRU) (1959)." Two handbooks—Handbook 79, "Stopping Powers for Use with Cavity Chambers," and Handbook 80, "A Manual on Radioactivity Procedures,"—are presently in preparation. Staff members have been very active in the work of the groups preparing these handbooks, as well as in the work of the International Commission on Radiological Protection (ICRP) and the recently established Federal Radiation Council. These groups have formulated recommendations which represent the latest scientific thinking in the broad area of radiation protection, quantities and units.

International Standards. The Bureau has always been an active participant in the activities of the International Bureau of Weights and Measures. In October 1960 the General Conference of Weights and Measures approved the extension of the work of the International Bureau into the area of ionizing radiation. A working group was set up to make recommendations on: Immediate and long-range programs for this area, a laboratory design for this work, laboratory equipment, and staffing. Members of the Bureau staff involved in neutron measurements, radioactivity measurements, and X- and gamma-ray measurements were invited to participate in this effort. During a meeting held early in 1961 this group considered the entire program and made recommendations. The staff of the International Bureau is now in the process of implementing these recommendations.

The National Bureau of Standards has constructed and is presently calibrating transfer instruments for X- and gamma-ray measurements which will be loaned to the International Bureau. These instruments will be calibrated by the International Bureau as well as by many of the national laboratories participating in the program. NBS has agreed to participate in one such intercomparison during 1962.

The International Bureau is also arranging for exchanges of radionuclide standards. NBS has participated in two such intercomparisons so far and others are planned for the future.

2.2. CHEMISTRY AND PROPERTIES OF MATERIALS

2.2.1. ANALYTICAL AND INORGANIC CHEMISTRY

As part of its program in the preparation, purification, and characterization of materials, the Bureau develops and improves methods for the measurement of the chemical properties, composition, and behavior of substances; prepares standard reference materials of known composition or properties; and makes accurate measurements of and collects data on chemical systems. It also studies the properties of molecules and atoms in their relation to chemical reactions, and provides technical and advisory services in specialized areas of modern chemistry.

The special investigations pursued during the past year in inorganic, analytical, and solution chemistry included studies of new as well as conventional methods for chemical separations and analyses by spectrochemical and other applied analytical processes. Substances of high purity were prepared, criteria developed for measuring purity, and chemical constants determined from pure materials.

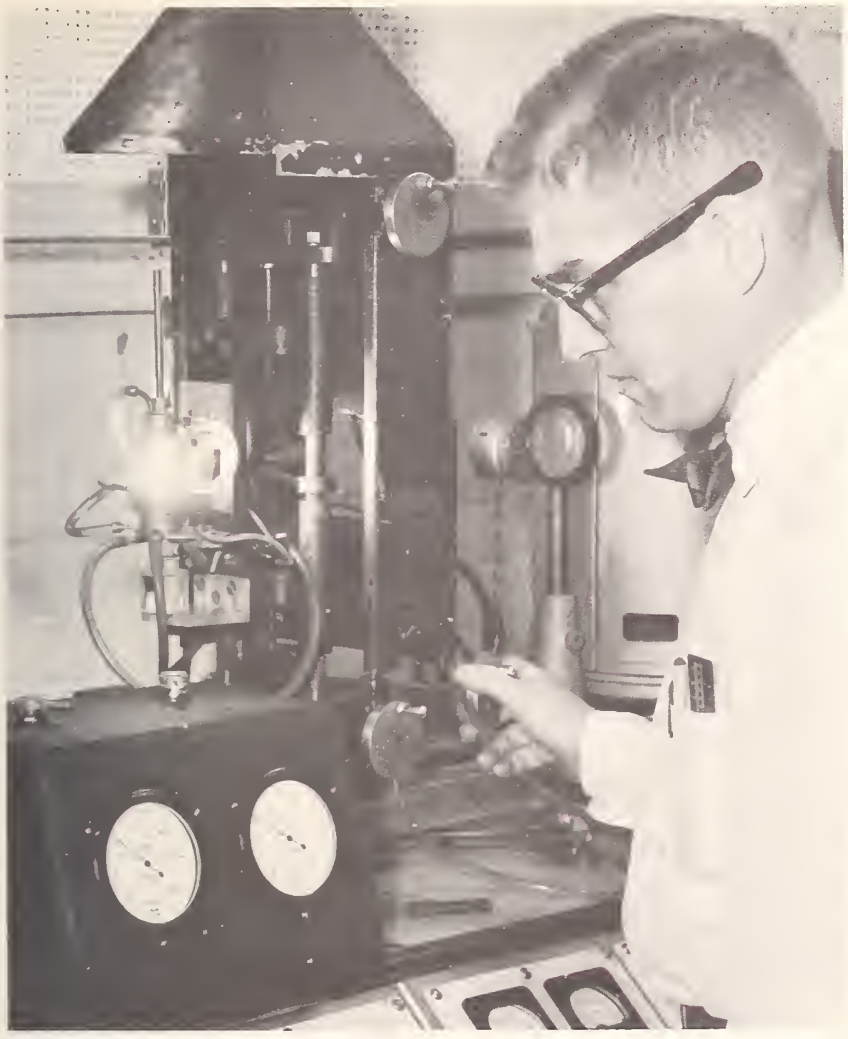
New programs were initiated in the fields of crystal chemistry, coordination chemistry, and resonance spectroscopy.

Applied Analytical Research. The establishment of a program on applied analytical research increased Bureau emphasis on instrumental methods of analysis. The program, concerned with the development and application of methods for analyzing and characterizing solids, liquids, and gases, incorporates classical and instrumental methods using both macro- and micro-techniques. New equipment obtained includes a high-temperature linear-programmed gas chromatograph, infrared spectrometer, mass spectrometer, automatic spectrometric-electrometric titrater, coulometric titrater, high-sensitivity polarograph, Kjeldahl nitrogen-determination equipment, and three types of micro-combustion apparatus: the Schöniger, the semi-automatic Dumas for nitrogen micro-determinations and the semi-automatic for carbon-hydrogen micro-determinations. In combination with spectrometric, electroanalytical, and microchemical equipment previously acquired, the Bureau is now well equipped to undertake a wide variety of analytical instrumental investigations and analyses.

Chemical Preparations. An interdisciplinary program was conducted on the redetermination of the atomic weights of chlorine and bromine. For the chlorine study, isotopic concentrates obtained from Oak Ridge National Laboratory were chemically purified and mixtures of known composition were prepared approximating the isotopic abundance ratio of normal chlorine. Only analysis of stock solutions of the isotope concentrates, also obtained from Oak Ridge National Laboratory, was involved in the bromine preparation. From mass spectrometric determinations of the absolute isotopic abundance ratio of these specimens the atomic weights of chlorine and bromine were calculated.

Spectrochemical Advances. A critical investigation on methods for the direct spectroscopic analysis of materials in solutions led to the development of a gas-stabilized arc of high stability. This arc burns in a chamber between a graphite anode and a water-cooled tungsten cathode. A flow of argon within the chamber and a graphite ring orifice control its position. For analyzing a sample, a capillary atomizer introduces the solution into the arc at a steady rate. The elements in the vaporized sample are excited to emit characteristic spectra with highly reproducible intensity. The arc offers promise as a source for analyzing materials in solution and for studying specific substances when a steady arc discharge is required.

In an investigation of the spectroscopic determination of gases in metals, a self-contained portable apparatus for handling gases and exciting their spectra was developed. The system is mounted on a metal table equipped



Arc source of high stability for exciting the spectra of materials in solution. The source may be used for spectroscopic analysis or in other work where high stability is required (page 72).

with a hydraulic lift and includes gas flow and pressure monitors as well as a chamber for evolving gases from metals and for exciting their spectra. The equipment may be moved and alined for use with different spectrographs or spectrometers throughout the Bureau laboratory.

During an X-ray spectrometric study of surface condition effects on the analysis of metals, the usual procedure of grinding a smooth surface on the sample was found to cause serious errors in some cases where hard and soft constituents are present in the metal. For example, if lead particles were smeared over the surface in leaded steel, high readings for lead were observed. Errors from this source were minimized by polishing the surfaces with diamond dust.

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Separation of Zirconium from Hafnium. Hafnium and zirconium, ordinarily very difficult to distinguish chemically, can now be separated by a single-step anion-exchange process. The separation for analysis is obtained by using a strong quaternary-amine anion-exchange resin column with diluted sulfuric acid as eluting solution. After separation of a mixture containing approximately 100 mg each of hafnium and zirconium, a spectrochemical examination showed only a few ppm (parts per million) cross contamination.

The method results from a systematic study of the elution behavior of a variety of zirconium and hafnium complexes. It is better adapted to the examination of hafnium-base alloys, because the hafnium is removed first in the elution cycle, and less trouble is encountered in the hydrolysis of ions of this element. In connection with this work, a procedure was developed for the quantitative analysis of zirconium in hafnium metal, which is used as a control-rod material in nuclear reactors.

Distillation Techniques Improved. Vapor-liquid chromatograms resulting from successive fractions of precise laboratory distillations are generally more informative than the boiling temperatures or the refractive indices because the progress in constituent separation is usually clearly shown. The method is now being used routinely in the distillation laboratory with improved results.

A new and better procedure for maintaining a constant flow of vapor to the column of a laboratory still was developed. Control of this vapor velocity is important because better separations of materials are obtained when the velocity is low but constant. The method depends on the use of a thermistor as a flowmeter to control the heat supplied to the vaporizer of the still. This process has a number of advantages over the usual method of controlling the heat supply by the changes in the vaporizer pressure.

A simple and reliable method was developed for cooling the reflux heads of laboratory stills to low temperatures. With this technique, the low temperatures may be maintained for long periods of time.

Accuracy for pH Standards Increased. Measurements of the acidity or basicity of solutions, expressed on the *p*H scale, are of far-reaching importance in chemical analysis, medical research, and modern industry. Because control of the *p*H is essential in many industrial processes, some years ago the Bureau took the lead in establishing a standard *p*H scale which would meet the practical needs of industry and possess, as well, the fundamental meaning demanded by science. Although standards for the adjustment of *p*H-measuring equipment have been issued by the Bureau for more than 15 years, fundamental difficulties in the calculation of a standard *p*H have made it necessary to limit the accuracy in the assignment of standard *p*H values to ± 0.01 unit. However, during the past year, a mutually satisfactory convention was developed in cooperation with the *p*H committee of the British Standards Institution, and the third decimal place is now being assigned to *p*H standard values.

A Standard for Blood pH. To discover the relationships that exist among physiological function, pathological condition, and *p*H, medical and biological laboratories have long studied the acid-base relationships in blood and other physiological fluids. Because blood is a well-buffered fluid, the changes in *p*H are very small and must be detected with precise *p*H-measuring equipment. To increase the accuracy with which these measurements can be made, the Bureau established a *p*H standard for determining the *p*H of blood and other physiological media with a *p*H of 7.382 at 37 °C (98.6 °F). The new standard, a mixture of phosphate salts, can be prepared from *p*H standard materials already issued by the Bureau.

Standard Hydrocarbon Blends. Eight standard hydrocarbon blends are now available from the Bureau for calibrating instruments used in analyzing gasoline and blending stocks. These standard samples—primarily intended for mass spectrometer calibration—are mixtures containing seven or eight pure hydrocarbons representing C_7 and C_8 paraffins and cycloparaffins in typical virgin and catalytically cracked naphthas. The standards may also be applicable for infrared and gas chromatographic techniques. The development of this new group of standard materials is part of an extensive and continual Bureau program to provide standard substances for chemical and physical uses.

Preparative Scale Chromatography. During the past decade, vapor-liquid chromatography has developed into an effective and widely used method of separating mixtures. Although it was utilized chiefly for analysis, its use in preparing small amounts of pure materials gradually expanded. As part of a program to extend the applicability of this method to routine purification, a process for automatically injecting samples and "cutting out peaks" to reject undesirable substances was devised. That is, to purify a specimen, any component which has a peak different from the characteristic peak of the specimen is automatically directed to a trap instead of the main ampoule. With these innovations, the chromatographic apparatus will operate automatically for long periods.

Additional improvements are being designed for preparative scale chromatography. Because purification of small amounts of samples is more effective in columns of relatively small capacity than that of large samples in large-diameter columns, the automatic cyclic operation of small to intermediate-size columns was chosen for further development.

Round-Robin Purity Determinations. Although any program directed toward the preparation of pure materials is completely dependent upon procedures for determining purity, the methods of gaging extent of contamination unfortunately do not have the necessary reliability. To obtain the best techniques for such a determination, a committee from the Bureau organized an international cooperative study several years ago of those techniques for determining purity which depend upon freezing-point depression by impurities. Four groups of samples were prepared under conditions designed to assure uniformity and verifiable purity. These speci-

mens were issued to 20 leading laboratories in six countries, including the Bureau.

During the past year, the round-robin results that became available demonstrated that accurate results can be achieved by this method. However, they also show that the sources of error are not always understood. From the results, the most effective processes for determining purity were found to be those in which changes in volume, heat content, or control of

Eight new standard hydrocarbon blends were issued for calibrating instruments used to analyze gasoline and blending stocks. Ampoules are filled in a controlled atmosphere with sufficient blend for one calibration (page 75).

the rate of freezing or melting were employed to judge the proportion of a sample which was in the liquid state at any temperature.

Crystal Chemistry. Research on crystal chemistry was expanded to obtain fundamental data on the formation, transformation, and purification of crystalline chemicals in terms of molecular structure. As all physical and chemical properties of solids are ultimately dependent upon structure, it is necessary to understand the relationship between structure and behavior of materials.

During the past year methods were evaluated for automatically recording precise single crystal X-ray diffraction intensities, for deriving the approximate atomic structure of crystals from X-ray diffraction data, for obtaining "flash" X-ray data from transient phenomena and for recording defects in high-purity crystals.

Three types of investigations were continued on purification by single-crystal growth: formation of pure single crystals, retention of impurities, and effect of defect structure on the properties of crystals.

Coordination Chemistry. Both theoretical and practical interest in the field of coordination compounds has increased in recent years because of the unusual properties that these compounds exhibit. Through coordination with suitable complexing agents many metal ions can be either activated or deactivated. In addition, many of the coordination compounds were shown to be useful catalysts whereas others were found to exist as intermediates in reactions. To study the preparation, stability, and mechanism and kinetics of formation of such compounds, the Bureau began an investigation of coordination compounds of the first transition metal series. The structure of these compounds is being studied with resonance spectroscopy and X-ray diffraction techniques.

Radiochemistry. Considerable effort was devoted to designing a new radiochemical facility for conducting fundamental investigations in radiochemical methods and for applying modern radiochemical techniques to existing research problems. By detecting tracer atoms and measuring the energy released from artificially radioactive species, the Bureau will study mechanisms of chemical processes and develop sensitive analytical methods. As part of this program, the analysis of trace constituents by neutron activation analysis will be stressed.

2.2.2. PHYSICAL CHEMISTRY

In response to the demand for more detailed information on the structure of molecules and elementary molecular processes, the Bureau initiated a program to consolidate and strengthen fundamental research on bulk properties of materials and macroscopic physicochemical processes. In the basic experimental phase of this program, special instrumentation was developed and precise data obtained on a wide variety of stable and short-lived molecular species and systems. An associated phase of theoretical research was begun to develop a coherent theory of molecular structure in relation to specific molecular reactivity.

Research activities during the year include the elementary chemistry involved in the synthesis of specially labeled compounds, in the processes induced by radiation and particle-impact, and in the reactions at surfaces. In addition, the structural and electronic parameters of relatively simple stable and transient molecules were determined and special apparatus was designed to measure relative isotope abundances for heavy elements, field emission and ionization at surfaces, reactions at very low temperatures, and fast reactions in transient complex systems.

Reactions of Atoms at Low Temperature. Chemical reactions between very reactive materials normally proceed extremely rapidly. By lowering the temperature at which these processes occur, it is possible to slow down the rate of reaction and thus make observations—for example, energies of activitations—which are difficult to make at higher temperature. Through recently developed techniques used in low-temperature research, chemical reactions with low activitation energies can now be studied. The virtual elimination of many secondary reactions at temperatures below 100 °K simplifies the interpretation of kinetic data and permits an accurate determination of kinetic parameters.

In NBS studies, hydrogen atoms were found to react with oxygen at 20 °K, with olefins at 77 °K, and with halogens at 90 °K. The primary reaction products are free radicals which have transient existence and subsequently dimerize and disproportionate to form stable compounds. The primary addition-reaction of hydrogen atoms to propylene was studied in detail and the activitation energy for this process was determined. At present, the effect of substituents on the addition of hydrogen to substituted olefins is being investigated.

Gas-solid Reactions at High Temperature. The failure of metals at high temperatures caused by corrosive attack of hot gases is often a limiting factor in the advancement of high-temperature technology. Because physical and chemical data relating to these phenomena are often lacking, the Bureau is conducting research on various aspects of high-temperature gas-solid interactions at the request of the Atomic Energy Commission. To facilitate this research, special equipment for molecular-beam studies was developed. By using the molecular beam, the reaction between chlorine atoms and a polycrystalline surface of nickel heated to temperatures between 1,100 and 1,600 °K was extensively investigated. Based on this study, the relative reactivities of different crystal planes of copper and nickel to halogens are being determined.

Light Elements. Data on the thermodynamic properties of light elements are essential for evaluating compounds composed of these elements as potential high-energy fuels. To obtain such data, the Bureau is conducting a comprehensive interdisciplinary program of experimental and theoretical work on light elements. For this research, which is under the joint sponsorship of the Atomic Energy Commission and the Department of Defense, "best" values were selected for the heats of formations of a variety of

Apparatus for obtaining nuclear magnetic spectra, which reveal important information on the local electronic environment of nuclei in complex molecules, on the sites of specific chemical reactivity, and on the pathways for communicating electronic effects within these molecules (page 82).

boron compounds containing hydrogen, oxygen, fluorine, chlorine, and bromine, and tables of thermodynamic functions for selected compounds were compiled. Codes, which were prepared for high-speed digital computer calculation of thermodynamic functions, were used to extend these functions to 6,000 °K for over forty compounds in the boron-oxygen-hydrogen-halogen-nitrogen system. (See 2.1.5, p. 53, 2.2.3, p. 86.)

Measuring Isotope Effects. By substituting radioactive isotopes for an atom in a molecule, the course of a substance can be traced through an entire series of complex chemical processes. However, sometimes a bond joining the isotope is altered in a rate-limiting step, causing a difference between reaction rates for the isotopic and non-isotopic modifications of a substance. The ratio of these rates is called the isotope effect. When the isotopic atom is involved directly, large isotope effects, designated primary, are obtained; when the isotopic atom is involved to a lesser degree, smaller effects, designated secondary, are obtained.

Recently the Bureau developed a simple method for measuring isotope effects. Two modifications of the reactant are used: One is labeled with an isotope at or near the reaction center, and the other is labeled with a second isotope at a point remote from the reaction center, where it does not affect the rate of reaction. If the first isotope alters the rate of reaction, the ratio of the two isotopes in the residual reactant and in the product changes as the

reaction proceeds. The value of the isotope effect can be calculated from this change.

The method has been applied to the study of a variety of chemical, physical, and biological processes. Thus, a five-fold tritium isotope effect was found in the oxidation of D-glucose-*1-t* with iodine. The commonly accepted mechanism for the oxidation of D-glucose-*1-t* with chlorous acid was disproved by the large isotope effect. Secondary isotope effects found in the oxidation of D-mannitol-*3-t* were attributed to hyperconjugation of the tritium in the activated enzyme-substrate complex. The method opens up a vast field for the study of reaction mechanisms.

Enolic Acids. Enolic acids, just recently recognized and considered as a large class of organic compounds, have not previously been investigated in any detail. Because these acids enter into unusual reactions, and because only isolated data have been recorded on any specific enolic acid, the Bureau is attempting a systematic determination of the reactions and properties of this new class. Enolic forms were found for beta diketones, hydroxyquinones, ascorbic acids, and many substances commonly considered as having activated hydrogen atoms. It is known that these acids differ from carboxylic acids in that they contain a characteristic C-C=C-OH group in lieu of the

well-known carboxyl group.

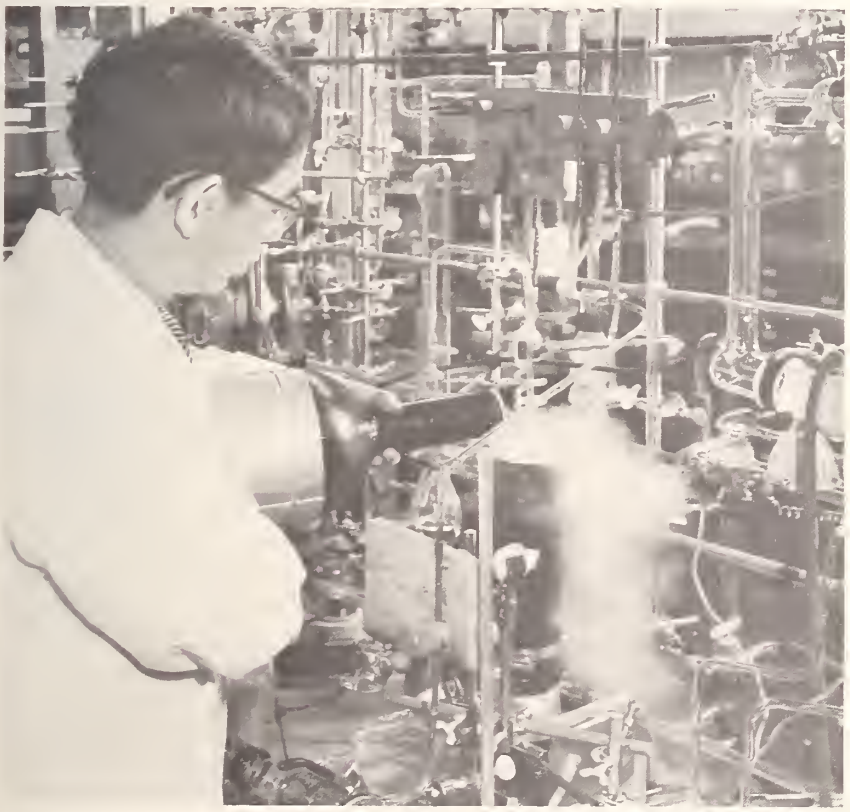
A series of enolic acids can be prepared by chemical treatment of hexahydroxycyclohexane. Removing hydrogen and eliminating water from the hexane produces hexahydroxybenzene, hydroxyquinones, rhodizonic acid and ultimately, cyclohexanehexone. The intermediates of this series establish reversible oxidation-reduction systems and provide a wealth of material for correlating molecular structure with chemical and physical properties. Improved methods were developed for preparation of tetrahydroxyquinone, rhodizonic acid, croconic acid, and other compounds needed for studying the acids. Mechanisms for aromatization and oxidation of the intermediates in the production of these compounds were formulated and are now being tested by model experiments.

Molecular Spectroscopy. As part of a continuing program devoted to solving fundamental problems in molecular structure, detailed investigations of the structures of several important molecules were carried out by spectroscopic studies in the ultraviolet, visible, infrared, and microwave regions. Through the use of microwave techniques, interatomic distances in a variety of hydrocarbons and their simple derivatives were measured with very high accuracy. Small variations detected in the carbon-carbon bond lengths in these molecules shed some light on the nature of the chemical bonds which are involved. The microwave studies also provided such scientific data as electric dipole moments and quadrupole coupling constants, which can be correlated with the geometric structure of the molecules.

Other spectroscopic studies involved free radicals and molecular fragments containing fluorine. The short-lived CF_2 molecule, which is an im-

portant intermediate in flames and electric discharges involving fluorine, was examined by flash photolysis and matrix isolation techniques. In the former method, the ultraviolet absorption spectrum was recorded during the very small fraction of a second that the molecule exists; in the latter, the CF_2 molecules were stabilized by isolating them in an inert matrix at a very low temperature. Related studies were carried out on the emission spectrum of CF from flames and discharges. In addition, an intensive investigation of the recently-discovered NF_2 radical was initiated. By measurement and analysis of the infrared spectrum of NF_2, the structure and vibrational frequencies of this free radical were established.

The nonresonant microwave absorption in compressed quadrupolar gases provided the basis for estimating molecular quadrupole moments. This type of absorption can be used as a sensitive probe for examining the nature of molecular interactions and relaxation processes. Values for the quadrupole moments determined for nitrogen, ethylene, and carbon dioxide are in good agreement with the estimates calculated by other methods.



The mechanism by which hydrogen atoms are removed from ethane during vacuum ultraviolet photolysis was determined. Such investigations give insight into the interactions of various materials with high-energy radiation **(page 82).**

The techniques of high-resolution nuclear magnetic resonance were applied to the structural classification of isomeric conformers of derivatives of cyclohexane. In general, the methods of analysis developed for the methyl disubstituted cyclohexane-1,3-diols appear to be applicable to the analysis of a wide variety of saturated cycloparaffins.

Uranium Standards. Because the value of a uranium reaction fuel depends on the abundance of the U^{235} isotope, accurate standards are required to make precise mass spectrometric determinations of this abundance. In cooperation with the Atomic Energy Commission, a surface-ionization mass spectrometer, which measures the isotope abundance in uranium oxide, was developed and used to check a series of standard samples. Relating to this work is the development of a method for determining the abundance of U^{234}.

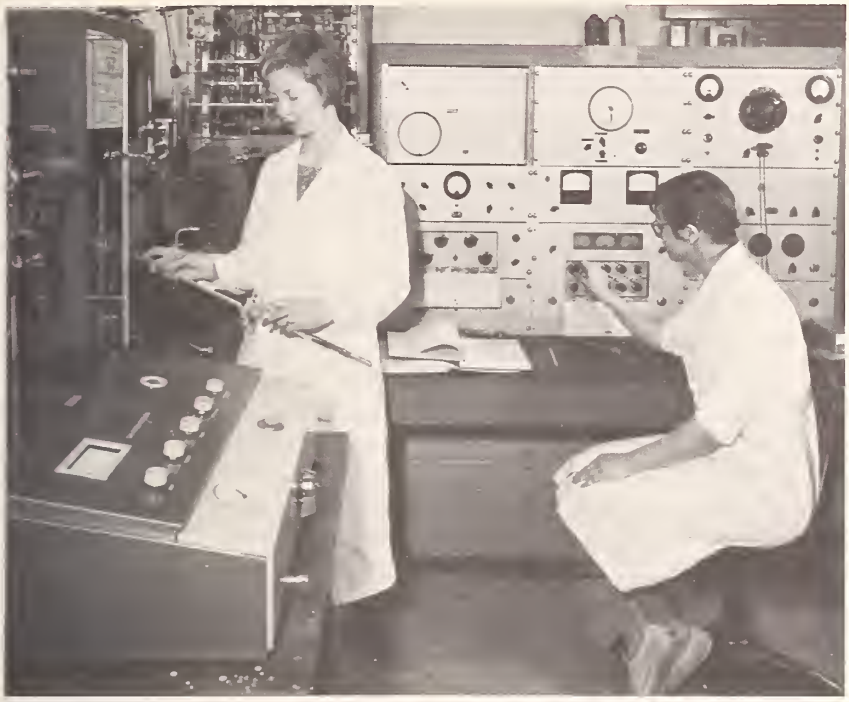
A special mass spectrometer was developed for analyzing uranium hexafluoride and is being used to evaluate standards having low concentrations of U^{235}. This instrument has been used to compare the natural abundances of uranium in samples from different geographical areas. Differences as large as 0.1 percent were detected.

Isotopic Abundance in Silver Checked. In the recent determination of the absolute isotopic abundance ratio of silver, one of the natural silver samples from Cobalt, Ontario, appeared to have a ratio significantly different from all the other samples. This difference suggested a naturally occurring variation in isotope abundance for silver. Consequently, mass spectrometric study, partly sponsored by the Atomic Energy Commission, was made on 13 samples of native silver from widely distributed deposits, including samples from Cobalt. No significant variation from normal abundance was noted for any of the samples. It is possible that the original Cobalt specimen was a portion of an extraterrestrial sample.

Photolysis of Simple Molecules. To gain insight into the detailed processes induced by different types of high-energy radiation, the Bureau is continuing work on the photolysis of simple molecules. The mechanism by which hydrogen atoms are removed from ethane during vacuum ultraviolet photolysis was determined. When subjected to far ultraviolet light, ethane molecules lose molecular hydrogen. Investigations on ethylene showed that molecular detachment of hydrogen occurs under the action of gamma rays, as well as under far ultraviolet light. The formation of molecular hydrogen by the action of far ultraviolet radiation on water vapor was also observed. This formation may account for the presence of hydrogen molecules in the upper atmosphere.

In another investigation, excited hydrogen atoms, which are present in the upper atmosphere, were produced in the laboratory in sufficient concentrations to study their reactions. Extremely active chemically, the hydrogen reacts rapidly with nitrogen molecules to form ammonia, and may produce small amounts of this gas at very high altitudes.

Radiolysis of Simple Hydrocarbons. Knowledge of the effects of ionizing radiation on organic compounds is of great importance because of



Knowledge of the effects of ionizing radiation on organic compounds is important because of the rapid development and extensive use of nuclear reactors, and because of the potential uses of high energy particles in synthesis. The mass spectrometer (background) and gas chromatograph (foreground) are used in the determination of primary processes in irradiated systems (page 82).

the rapid development and extensive use of nuclear reactors, and because of the potential uses of high-energy particles in synthesis. In order to provide fundamental data on the behavior of irradiated compounds, the Bureau is cooperating with the Atomic Energy Commission in research on the radiolysis of simple hydrocarbons. Molecular elimination processes which occur in the gas-, liquid-, and solid-phase radiolysis of ethylene, ethane, propylene, propane, and isobutane were investigated. In general, by utilizing partially and fully deuterated compounds, the several ways in which these molecules may decompose can be unambiguously determined. For instance, in all the hydrocarbons studied, hydrogen molecules were found to split off from a single carbon atom as well as from adjacent carbon atoms. In addition, by using radical scavengers to eliminate radicals, methane was observed to be produced by molecular elimination from ethane, propane, and isobutane. Studies of the effects of temperature, pressure, and inert gases on the different processes aided in determining the relative importance of excited-molecule decompositions in radiolysis.

Radical Reactions Formed by Irradiation. Detailed information on elementary reactions is required to understand such complex phenomena as oxidations and thermal decompositions. To obtain these data vapor-phase

radiolysis of selected organic compounds, such as azomethane and acetone, was intensively investigated for the Atomic Energy Commission. The results can be explained on the basis of free radical reactions similar to those occurring in the photochemical decomposition of these compounds. The excellent agreement between the rate constants for the reactions which the methyl radicals undergo in the radiolysis, as compared to the rate constants obtained in earlier photolysis studies, indicates that only thermalized methyl radicals take part in the reactions.

Electron Emission from Surfaces. As part of a program to characterize the surfaces of materials, the field distribution of electron emission near the surface is being determined. For this research, the temperature variation of electron emission in the field-emission region was studied. Results confirmed the theoretical relation that the fractional increment in emission current varies as the square of the temperature. For an emitter of known work function, the slope of the curve, depicting current increment versus the square of the temperature, yields a precise value of the average field at the surface of the emitter. This graphic method gives values which are more accurate than those obtained by the conventional method which depends on the measurement of the radius of the emitter with an electron microscope. Field emission from niobium, both above and below its superconducting transition temperature, failed to reveal a current increment attributable to an energy gap associated with this transition.

2.2.3. MINERAL PRODUCTS

To provide basic information on a wide variety of inorganic, nonmetallic substances, the Bureau conducts a two-fold program. One aim of this program is to obtain precise values of specific constants and fundamental data that are important to the scientific community. Related standard samples and information on engineering research are developed as required. A second aim is to devise techniques for preparing materials and measuring their properties under carefully controlled conditions. This work includes the extension of physical property measurements to the extremes of high and low temperature, to high pressures, and into the realm of very pure substances.

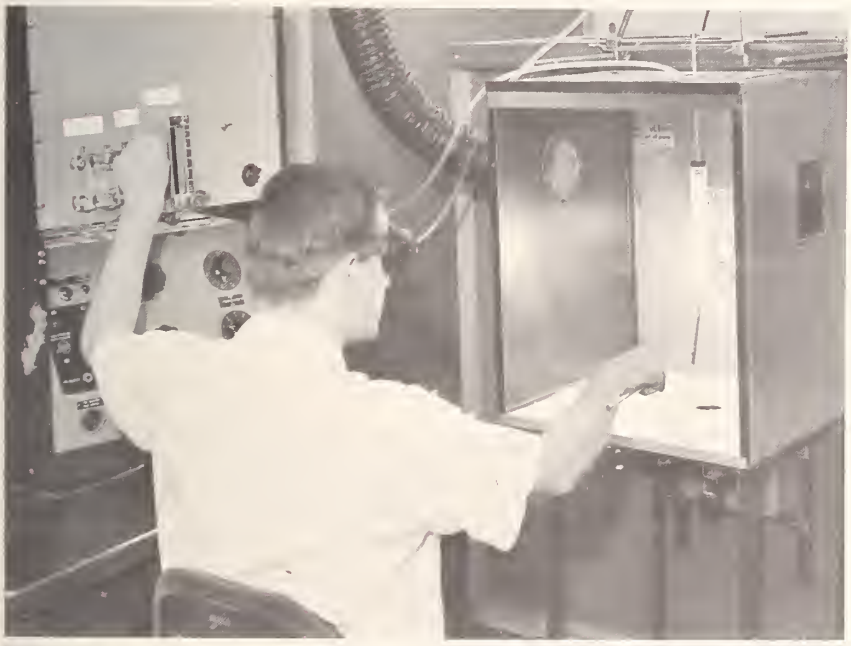
During the year significant advances were made in developing techniques for growing single-crystals of inorganic nonmetallic materials from the melt. This research is being expanded to the study of fundamental mechanisms of crystal growth processes.

Crystal Growth. Single crystals of high purity and perfection are extremely important for many fundamental studies of the solid state and for developments in electronics technology. Some of the techniques now used in basic and applied research are so sensitive that they are affected by the residual impurities or imperfections present in refractory oxide crystals of the highest quality now available. Thus, methods are needed for growing such refractory crystals as sapphire (Al_2O_3) and rutile (TiO_2) with much greater control over purity and perfection.

As part of a program for the Atomic Energy Commission, the well-known Verneuil process, which uses an oxyhydrogen flame, was used to produce single-crystal rods of rutile with the conventional orientation of crystallographic axes as well as various uncommon orientations. The Verneuil apparatus was modified to incorporate a radiofrequency plasma torch capable of considerably higher temperatures than the oxyhydrogen flame. Improvement upon the Verneuil process is expected to give better control over growth of many refractory crystals.

Model Defect Structure. The presence of an impurity atom in a crystal causes a distortion or defect in the crystal structure at that point. As various types of defects are possible, it is usually difficult to predict what type of defect will result from the introduction of a given impurity into a given crystal. Sometimes the type of defect can be determined by assuming a model for the defect, calculating the contribution of the defect to various physical properties, and comparing the results with measurements of these properties. The Bureau developed a particular model and a method of calculating the temperature and frequency dependence of the resulting energy loss. Predictions determined from this work were compared with experimental results of thorium oxide containing small amounts of calcium oxide.

It was assumed that calcium atoms would substitute for thorium atoms in the thorium oxide structure and that one oxygen vacancy would be asso-



The well-known Verneuil apparatus for growing single crystals of mineral substances was modified by using a radiofrequency plasma torch instead of the usual oxyhydrogen flame. Single crystals of high purity and perfection are important in studies of the solid state and the fundamental properties of materials (page 85).

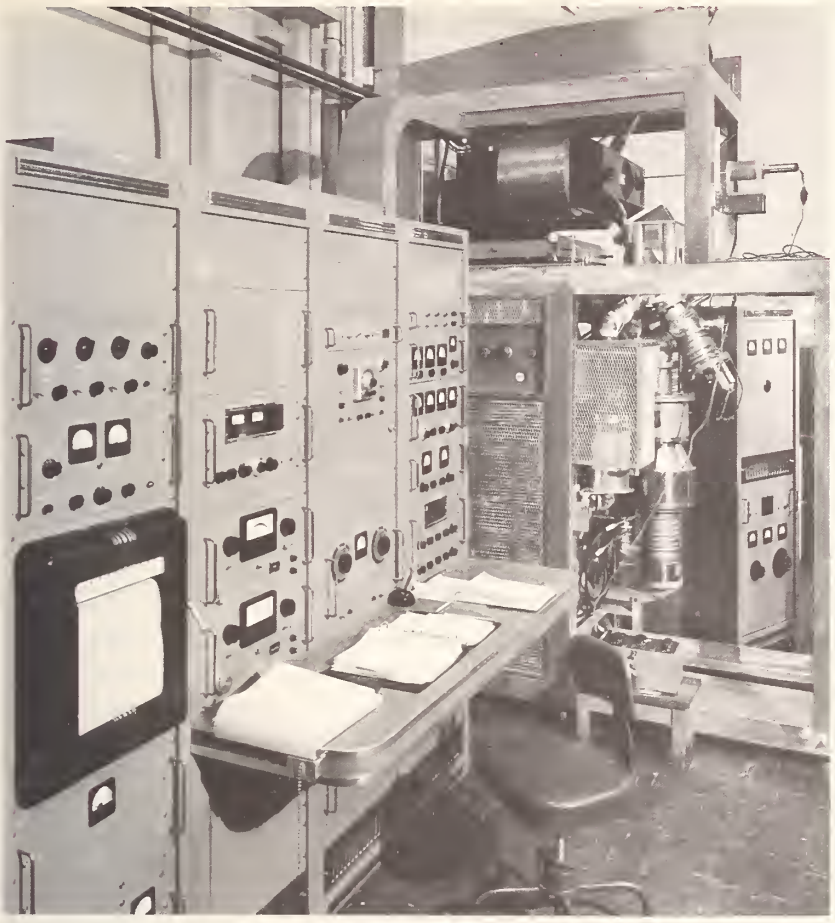
ciated with each calcium atom if the temperature was not too high. In the absence of stress or electric field, each oxygen vacancy under the influence of thermal vibration will move around its associated calcium atom; that is, the vacancy will "jump" randomly from one to another of the eight oxygen sites neighboring the atom. If an alternating electric field is applied, the motion will no longer be completely random but will have a superimposed regular motion driven by the field. Although this type of motion will also occur if an alternating shear stress is applied, the details of the regular motion depend on the type of drive (stress or electric field) and on the orientation of the crystal with respect to the driving force.

The theory was worked out in detail and a peak was predicted in both the mechanical loss (internal friction) and electrical loss (dissipation factor) as a function of temperature. Experimental results, which fit this function very well, suggest that the model correctly describes the behavior of oxygen vacancies associated with calcium atoms for low concentrations of calcium. Work is now underway on other defect models and other experimental materials.

Vaporization Data. As part of a continuing program to furnish basic data on some of the thermodynamic properties of light-element refractory metals and oxides, investigations on the vapor pressures and rates of vaporization of such substances were undertaken at the request of the Advanced Research Projects Agency. Heats of vaporization of platinum, iridium, rhodium, and palladium at 25 °C, as calculated from measurements of the vapor pressures, are respectively 134.9, 159.9, 132.5 and 89.2 kcal/mole. Preliminary data was obtained on the rates of vaporization of alumina in a vacuum and in the presence of water vapor. (See also 2.1.5, p. 53.)

A major uncertainty in determining the thermodynamic data arises from the measurement of temperature. Although the uncertainty for the palladium data was considerably reduced with a technique in which a blackbody hole was drilled in the sample, the uncertainty can generally be best reduced by having more complete data on the emissivities of the samples. To facilitate such measurements, apparatus was constructed to determine the angular spectral emissivities of samples over a wide temperature range. This apparatus is being used to measure the emissivities of many light elements and compounds.

A second problem in interpreting vaporization data is associated with the identification of the vaporizing species. For example, to obtain the vapor pressures and heats of vaporization of the platinum metals, the gas species were assumed to be monatomic, although diatomic molecules could also be present. Only with the aid of a mass spectrometer can the species be determined with a high degree of assurance. Such a mass spectrometer was specially designed for high-temperature vaporization studies in a program sponsored by the National Aeronautics and Space Agency. The direction focusing instrument used by the Bureau is of the Chupka-Inghram design which pioneered the application of mass spectrometers in this type of research.



One of the basic problems in studying the behavior of materials at high temperatures is identification of the vaporizing species. This special mass spectrometer was designed to identify the gas molecules which vaporize from solids or liquids at temperatures up to 2,500 °C (page 86).

By using the apparatus, it is possible to identify the gas molecules which vaporize from solids or liquids at temperatures up to 2,500 °C. In addition, the relative abundance or partial pressures of the gas species may be determined. The instrument will be used to obtain basic data on the vaporization of a wide range of high-temperature metals and compounds which are important for rocketry, direct-energy conversion systems, and other technological advances.

Mechanical Properties of Ceramic Bodies. The progress of high-temperature technology is hampered by the inability of materials to withstand environmental design conditions and stresses. One of the foremost obstacles blocking the improvement of existing materials and development of better ones is the lack of fundamental knowledge on the structural and thermal dependence of the mechanical properties of polycrystalline solids.

To bridge this gap, the Bureau is conducting a study on the influence of microstructure on the mechanical properties of brittle, glass-free polycrystalline bodies. One phase of this program, sponsored by the Atomic Energy Commission, involves the study of strength, a structure-sensitive property of a ceramic. Although strength is known to be very dependent on porosity and grain size, only the general trend of this dependency is known. An empirical general expression, which relates strength in terms of porosity and grain size, was formulated. This equation has been applied to a number of ceramic bodies such as alumina, thoria, urania, and chromium carbide.

The apparent temperature dependence of the two constants involved in the equation indicates either that the form of the expression is incorrect even though it is generally applicable, or that the apparent porosity and grain-size effect is not produced solely by internal geometry changes, but also by some other temperature-dependent factors acting in concert with the above changes. The temperature dependence of the constants is currently being investigated to determine the existence and nature of any associated factors.

The strength of a porous body is partially dependent on the extent of continuity within its weakest section. It has been proposed that the weakest region within a brittle polycrystalline body is the area of contact or bonding between grains. Accordingly, the strength of such a body would depend on the relative size of the total projected area of contact or bonding traversed by an irregular surface of minimal area passing intergranularly across the load-bearing cross-section. Because porosity, as related to strength, is believed to be but an indirect, relative, inverse measure of the relative size of such a projected area, an attempt is being made to determine the relative size of this area, and to define the structure sensitivity of strength directly in terms of this parameter instead of porosity.

Similar related studies are being conducted on the structural dependence of the elastic properties of brittle polycrystalline bodies.

Resonance Techniques for Determining Elastic Moduli. Resonant vibration techniques for measuring elastic moduli of glasses and ceramic materials both at room temperature and elevated temperatures were developed during the past few years. As the techniques were improved, it was found that the equations which were used for computing the moduli from the resonance frequencies were not accurate. After systematic studies, the technique for determining these frequencies was refined to the point where the primary limitation on their use for computing the elastic moduli is the accuracy of the corresponding theoretical equations themselves. Solution of these equations depends on the geometry of the specimens, and generally cannot be obtained in closed form. Empirical relations for specific geometries were developed by accurately machining steel specimens of uniform elastic moduli and experimentally determining their resonance frequencies. The results are usually in the form of a table of correction factors of the theoretical solution for various geometries.

Similar empirical relations were also developed for other modes of vibration. For example, Young's modulus can be computed from the flexural

vibrations of cylindrical and rectangular bars, and shear modulus can be accurately determined from torsional vibrations of square bars. At present, equations are being developed for calculating Young's modulus from the longitudinal vibrations of square and cylindrical bars.

Effects of Roughness on the Oxidation of Iron. Rough and smooth metal surfaces have been observed to oxidize at different rates. For example, roughened iron surfaces oxidize at a lower rate than smooth ones. This difference, thought to be related to variations observed in the bond strength of alumina and zirconia coatings flame-sprayed on rough and smooth iron surfaces, was systematically investigated to determine the oxidation rates of both types of iron surfaces. This work is one phase of a research program on particle-impact coatings requested by the Wright Air Development Center.

Experiments demonstrated that the over-all oxidation rate, and even the rate per unit area, decreased for ingot iron roughened by grit blasting and oxidized in air at 800 °C. This reduction in rate was found to be caused by neither surface contamination, nor surface cold work, but by stress-induced voids that form in the scale layer on roughened surfaces. By acting as barriers to the outward diffusion of iron ions, the voids lower the rate at which roughened specimens oxidize. This interpretation was confirmed by microscopic examination of specimens roughened by simply machining small grooves in the surface. The voids clearly formed over convex portions of the iron surface with small radii of curvature.

This effect determines the complex course of the oxidation of impure iron with an initially smooth surface. In the early stages of oxidation, the rate followed a parabolic curve with the rate constant equal to the slope of the curve. With continued oxidation, however, the surface became roughened and the rate constant decreased. After a transition period, parabolic oxidation was re-established but with a lower rate constant. On the other hand, specimens of high-purity iron (99.9903%) with smooth surfaces not only remained smooth throughout a three-hour oxidation period but they also oxidized parabolically with a single rate constant.

Standard X-Ray Diffraction Patterns. Standard X-ray diffraction patterns in the form of card files are widely used in research and industry as a rapid and accurate means of identifying crystalline materials. To aid in producing new patterns, the Bureau developed a controlled humidity chamber. This chamber provides the appropriate atmosphere in which any hydrate may be maintained in equilibrium while X-ray patterns are being made. By utilizing this technique, hydrates not previously available can be effectively measured.

A camera was designed to measure the unit cell parameters of crystals to an accuracy of one part in 100,000. A back reflection focusing type, the camera has a glass photographic plate to minimize film shrinkage errors. It employs a microfocus X-ray source and is placed in an insulated chamber with a temperature control constant to 0.01 °C. Data obtained with this instrument will be useful for studying the relation of cell size to variation

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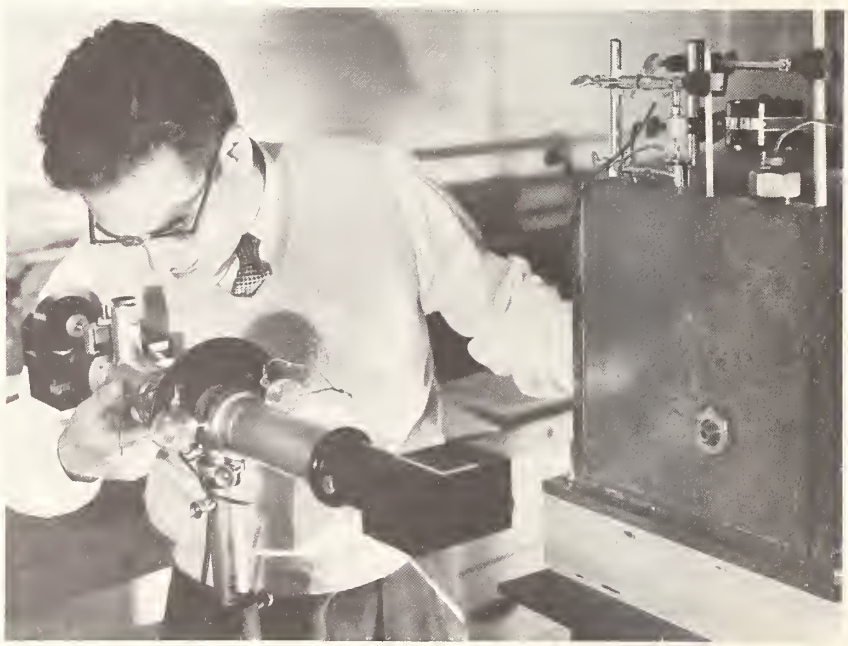
of composition and to defect population as well as for determining the interrelationship of atomic constants such as Avogadro's constant, wavelength of X-rays, and atomic weights.

Deuterium Isotope Effect in Glass Transformation. Explicit understanding of the glass transformation process, which results in formation of the vitreous state, requires identification of modes of molecular motion. Such motions, immobilized when a substance is cooled through the temperature region of glass transformation, can be studied in glass-forming aqueous solutions by measuring and interpreting deuterium isotope effects on glass transformation temperatures. A glass transformation temperature of a non-crystalline substance is an operationally specified temperature below which the substance exists as a glass, and above which it exists as an equilibrium super-cooled liquid.

Many aqueous solutions form glasses which have transformation temperatures in the neighborhood of −150 to −125 °C, as determined by differential thermal analysis. The value for an individual solution does not vary with solute concentration below approximately 10 mole percent. Complete substitution of D_2O for H_2O as the solvent in sulfuric acid solution raises the glass transformation temperature 2.6 °C, from −129.5 to −126.9 °C. For partial D_2O substitution the rise is linear with the extent of substitution. For hydrochloric acid the rise for complete substitution is 3.7 °C, from −145.0 to −141.3 °C.



An improved understanding of intermolecular forces is the objective of this investigation of the effects of pressure on the refractive index of liquids. The liquid under investigation is placed between the plates of a special interferometer (in box, right) and the interference fringes are observed visually (page 91).

These deuterium isotope effects are caused by the difference in atomic masses of deuterium and hydrogen—deuterium is twice as heavy as normal hydrogen. Because the two types of atoms are isotopes, they are approximately equivalent in most other aspects. Thus, with other variables remaining nearly constant, the isolated effect of the mass change can be measured. Final molecular interpretation of these results requires additional information about the magnitude of the potential energy barriers separating successive molecular configurations in the equilibrium super-cooled liquid. However, these data are roughly consistent with the existence of successive molecular configurations differing in the relative position of individual water molecules with respect to their neighbors.

Ultra Low-Conductivity Water. Water, because of its abundance, its importance to the physical sciences, and its role as a life-supporting liquid, has been the subject of intense study for many years. Yet, despite all this research, water apparently had not been produced with a small ionic content.

The Bureau, however, recently succeeded in preparing water of extremely low ion content by applying an electrophoretic ion-exclusion technique. The water obtained has an electrical conductivity of 0.039×10^{-6} ohm^{-1} at 18 °C, indicating a residual ion content which is equivalent to a sodium chloride concentration of one part per billion. Containing less than one-third of the ionic impurities of the water prepared by Kohlrausch and Heydweiller in their historic purification experiments in 1894, this water approaches ideal purity and its conductivity is closer to the theoretical value than that of any water preparation of which has been previously reported in the literature.

In designing the purification procedure, two principal considerations were involved. First, instead of using multiple distillation as in the classic experiments, an electrophoretic procedure was applied. In this way purest water was obtained in 2 hours. Second, the purification apparatus was designed to recirculate the purified water continuously through the electric field, thus immediately removing any ions which might originate from the walls of the apparatus and contaminate the already purified water.

Because this pure water has ultra low conductivity, it was used to study the dissociation equilibria at different temperatures. The cross relations of physical data which describe such important properties of water as the dissociation constant, were verified from this study.

Index of Refraction of Liquids. To develop a better understanding of intermolecular forces, the effect of pressure on various materials is being studied. As part of this program, the effects of pressure upon the refractive indices of benzene, carbon tetrachloride, methanol and water were determined. An interferometric technique was developed to measure the index of refraction to the fifth decimal at pressures as high as 1 kb and at temperatures between 10 and 60 °C.

For the measurements, the desired liquid is enclosed in part of the interferometer (the etalon) which, in turn, is contained in a pressure vessel having observation windows. A collimated beam of light enters the con-

tainer and produces an interference pattern which is observed outside the vessel. As pressure is applied to the system, the effect of pressure on this pattern is recorded. Distortions in the windows of the vessel produce no significant errors, while distortions of the interferometer, which is subject to hydrostatic pressure, can be evaluated satisfactorily.

In the absence of intermolecular interactions strong enough to alter the electronic energy levels in the molecules significantly, the index of refraction is expected to be a function only of the specific volume. However, interferometric data show that even at constant volume, the index of refraction for a given liquid depends upon the temperature. This dependence can arise from a change in either the resonant frequency or the intensity of spectral absorption lines. To understand better the nature of the interactions involved, the Bureau is extending the study of pressure and temperature effects over the whole visible spectrum.

2.2.4 METALLURGY

Metallurgical research at the Bureau is directed toward a better understanding of the properties of metals in order that improved metals and alloys may be developed to meet new requirements or to give better performance. Fundamental information is needed, and much of the work is designed to further our understanding of metals and alloys in terms of their constituent atomic units. Particular emphasis is placed on problems related to metals subjected to high temperatures, and to corrosion and fatigue, and to the preparation of pure metals. Crystal growth, electronic properties, atom mobility, and lattice imperfections of metals are studied as well as the effect of treatment, fabrication, and conditions of service on their structure, behavior, and properties.

Vapor-Phase Crystallization Studied. To obtain a better understanding of the process of crystallization of metals, quantitative measurements of vapor-phase crystallization under precisely known conditions are being made. This work includes kinetic studies of the growth of potassium and mercury crystals as a function of vapor supersaturation, temperature, and amount of impurities present. Recent results on high purity potassium distilled in ultra-high vacuum showed that potassium crystals could grow at very low vapor supersaturations; that is, in the absence of surface nucleation. The experiments were performed in carefully baked-out and outgassed tubes and contradict the results obtained in experiments with crystals of lower purity or less well prepared growth tubes. Growth rates, measured across two opposite faces on a potassium single crystal about 1 mm in diameter, were as low as 1 A per second at the lower supersaturations. The mercury crystals under study are in the form of "whiskers," about 100 A in diameter and 5–25 microns in length. As these nearly perfect crystals grow in an electron field emission tube, precise measurements of length, radius, and other properties can be made as a function of time, temperature, and supersaturation.

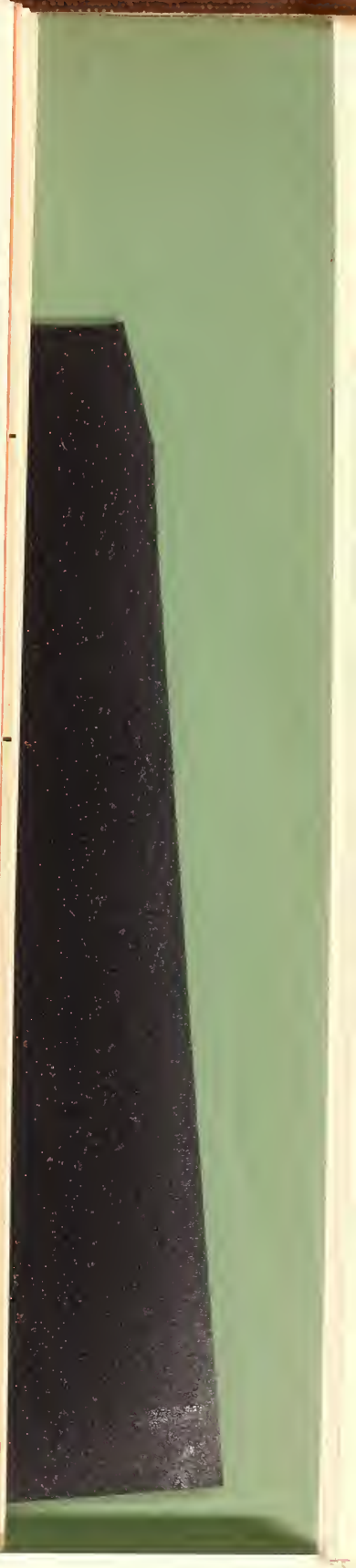
Oxidation Processes Studied. During the year a study was made of the influence of a metal substrate on the properties of the oxides formed on the metal surface. Experiments with aluminum single crystals disclosed that the crystallographic orientation of the substrate upon which the oxide grew decidedly influenced the shape and orientation of the markings appearing in the oxide film. When the substrate was melted, the oxide film—because of its higher melting point—remained intact. When the substrate recrystallized, the film retained its original markings, with new markings, characteristic of the new substrate orientation, being introduced. Each time this process was repeated. new markings appeared.

Another study, concerned with the sites of passive film breakdown on iron, revealed the influence of the crystallographic orientation of the metal surface. This breakdown occurs at discrete sites whose number per unit area depends upon the crystallographic orientation of the surface bearing the film. This study also revealed that the formation of the passive film is a two-step process. To gain a better understanding of this phenomenon, studies on the formation of the first monolayers of oxide were initiated. The surfaces of iron, nickel, titanium, and mercury whiskers were observed in a field emission microscope and studies of the oxidation process are under way.

Nuclear Magnetic Resonance. Nuclear magnetic resonance techniques are being applied to the investigation of the electronic band structure of hard metals (intermetallic compounds) having the crystal structure of sodium chloride. In metals, the position of the center of the nuclear resonance line usually shows a relative displacement toward lower fields, compared with salts of the same atom. This paramagnetic displacement (known as the Knight shift) is thought to have its origin in the contact hyperfine interaction between the "*s*" conduction electron spin and the spin of the nucleus under observation. Both the tantalum resonance in tantalum carbide and the niobium resonance in niobium carbide were measured and found to have diamagnetic Knight shifts. These results suggest the atomic *s*-levels are depressed in the solid completely below the Fermi level and thus do not contribute to the high electrical conductivity of these materials.

Superconductor Materials. A recent observation that the niobium-tin (Nb_3Sn) intermetallic compound retains its superconducting properties in magnetic fields of the order of 100 k Gauss stimulated interest in the basic understanding of "hard" superconduction, and in the possibility of fabricating superconducting magnets for the production of very high magnetic fields. The Bureau's cryogenic engineering laboratory at Boulder (Colo.) plans to make a magnet from Nb_3Sn specimens prepared in the Washington, D.C., laboratories (see p. 143). The specimens are composite wires 0.015 in. in diameter consisting of a core of Nb_3Sn sheathed in pure Nb. These wires remained superconducting in magnetic fields as high as 185 k Gauss.

Little information is available on other types of alloys which may be utilized as windings for high-energy cryogenic magnets. Hence, extensive research and testing programs are being formulated to enhance our knowl-



edge of these alloys and broaden their applicability, particularly in the area of controlled nuclear energy.

Soft X-ray Spectroscopy. Interest has recently been stimulated in soft X-ray spectroscopy because it provides information on the density of electronic states in the valence band of solids. To provide such data on metals, the Bureau is constructing a soft X-ray spectrometer which employs a curved glass grating. It is ruled with 30,000 lines to the inch, and has photomultiplier detection. Initially the research effort will be directed toward obtaining emission spectra from intermetallic compounds and their constituents over a wide temperature range. The results will contribute critical data for the eventual formation of a quantitative theory of bonding in metals and alloys.

A measuring microscope is used to measure the distance between two faces on a potassium crystal growing from the vapor phase inside a dewar vessel. Inset shows potassium crystal about 0.9 mm in diameter. Studies of fundamental crystallization processes in metals provide a better understanding of the physical properties of the materials (page 92).

Diffusion Studies Continued. Theoretical studies of the details of atomic motions which cause diffusion in crystalline solids were continued. If a metal containing dissolved impurities is held in a temperature gradient, a current of impurities is induced until a steady state gradient is established. The induced current, the steady state gradient, and the mean atom drift velocity in a dilute alloy were calculated in terms of the kinetic parameters describing the jumps of the atoms from one lattice site to another. General equations were developed which can also be applied to diffusion in other types of gradients, such as a chemical concentration gradient in a non-dilute alloy or an electrical gradient.

Dislocations Observed in Metal Foils. A study was made of the relation of surface chemical etch pits to dislocations in thin single-crystal copper foils. The experimental technique involves direct observation of dislocations by transmission electron microscopy. The results indicate that certain etching solutions are sensitive to the presence of dislocations and other crystal defects, but that a precise one-to-one relation is not generally obtained. The method should be applicable to many fundamental studies of corrosion reactions on metal surfaces.

Phase Diagram of Quaternary System Completed. The increasing use of multicomponent alloy systems to obtain desirable mechanical properties and corrosion resistance of metals at high temperatures has focused attention on the solid-state reactions occurring when a complex alloy is heated at different temperatures for prolonged periods. Alloys whose basic compositions include iron, chromium, nickel, and moylbdenum compose one of the important alloy systems in this class. In determining the composition limits of the reacting phases at various temperatures in this system it was found necessary to redetermine portions of the equilibrium phase diagrams in the Cr-Ni and Fe-Mo binary systems. Considerable new data also had to be obtained on the Fe-Mo-Ni and the Ni-Cr-Mo ternary systems before the Fe-Cr-Mo-Ni quaternary system could be completed.

Mechanical Properties of 17–7 PH Stainless Steel Investigated. The mechanical properties of 17–7 PH (17 percent chromium-7 percent nickel) stainless steel foil were determined following various aging treatments. An explanation for the brittle condition resulting from aging at temperatures less than about 970 °F was evolved. It was found that the improved strength properties and retention of significant ductility of material aged above 970 °F results from the simultaneous precipitation of an extremely fine compound within the martensite grains, and the reversion by transformation of some body-centered cubic alpha (martensite) to face-centered cubic gamma (austenite). The change in properties and structure was observed by using X-ray diffraction, integrated intensity measuring techniques, and recently developed bulge-test equipment.

Identification of the hardening compound formed during aging was accomplished using an electron microscope and selected area-diffraction techniques. Examination of carbon extraction replicas of samples aged for 68 hours

Studies of physical and chemical processes on metal surfaces are made at magnification of a million times by field emission microscopy. The image of the metal surface shows up on the fluorescent surface of the bulb in the lower right corner of the picture (page 93).

revealed crystallographic structure of the precipitate to be the cesium chloride body-centered-cubic type with a lattice parameter of 2.909 A.

Properties of Iron Reviewed. A comprehensive review and compilation of all of the known physical, mechanical, and thermodynamic properties of iron was completed and published. The data include all property

values so far established for the NBS high-purity irons, as well as values for other irons of higher than commercial purity.

Quantitative Metallography Obtained with Digital Computer. The Bureau's SEAC computer, SADIE picture scanner, and "STRIP–II" library of computer sub-routines were used to work out methods for performing quantitative metallographic operations on micrographs, both of metal powders and of normal polished sections. With this process, metallographs are automatically scanned and translated into language suitable for computer input. Particle-size and grain-size analyses are typical of the operations performed. An additional sub-routine, producing 11 parameters descriptive of metallographic grains, was composed and incorporated into the STRIP–II series. Preliminary planning was completed for additional routines and for the extension of the work to larger pictures when the Bureau's new Pilot computer becomes fully operative.

Gases in Metals. The first standards for the hydrogen content of titanium and its alloys were certified and made available. These standards consist of titanium sheet at three levels of hydrogen content, 32, 98, and 215 ppm. A study is now being conducted to establish standards for the oxygen content of several of the titanium alloys. In the ferrous alloys, work is progressing on two new standards representing vacuum-melted steel and stainless steel.

Gage Blocks. The Bureau is continuing its long-range program to develop gage blocks that will maintain a dimensional stability of 0.1 or 0.2 microinches per inch per year. Thus far, several groups of experimental blocks have met this stability requirement. Nitrided 410 stainless-steel blocks with annealed cores demonstrated especially good stability over a period of three years. In addition, these blocks have other desirable characteristics, such as high hardness, ability to take a high degree of surface finish and parallelism, resistance to corrosion, and a favorable coefficient of linear expansion. Other promising series include blocks of 52100 steels, and experimental steels were designed and processed that are expected to exceed the performance of the 410 composition. Studies are being conducted to establish the inter-relations of chemical composition, heat treatment, structure, residual stresses, surface films, case depths, and dimensional stability of gage blocks.

Creep Studies Continued. To provide basic information on the creep of metals, studies are continuing to be carried out on the creep characteristics of the nickel-copper system under carefully controlled conditions. In a recent investigation, the effects of cold-drawing on the creep resistance of high-purity nickel, and two nickel-copper alloys (70 percent Cu–30 percent Ni; 30 percent Ni–70 percent Cu) were evaluated, and the results were correlated with those previously obtained on cold-drawn copper and annealed metals and alloys. It was found that, in general, the resistance to creep at temperatures below recrystallization was increased by cold-drawing and (at all temperatures investigated) by mutually alloying the nickel and copper. At creep temperatures above recrystallization, the effects of cold-working

were practically eliminated and the creep behavior of the initially cold-worked metal was similar to the corresponding metal as annealed.

Organic Films Increase Fatigue Strength. Fatigue, or the failure of metals under repeated loads is profoundly affected by the environment at the surface of the metal. With many metals, the surface reactions occurring in a normal indoor atmosphere are sufficient to reduce fatigue strength below that observed in vacuum or in an inert atmosphere. Recent work, under the sponsorship of the National Aeronautics and Space Administration, showed that the deleterious atmospheric effect was virtually eliminated when the surface was coated with certain organic liquids that form adherent films on metal surfaces. In extensive tests the beneficial effect of the films was operative during both the crack initiation and crack propagation stages of fatigue failure.

Metal Polarization Indicates Corrosion Rate. During the past several years the polarization characteristics of metals were studied while the metals were corroding in aqueous solutions. The studies definitely show that the effects of factors such as precipitation, temperature, inorganic coatings, and metal composition upon the rate of corrosion can be determined directly from polarization curves, and that the performance of metals can be reasonably well predicted under many corrosive conditions.

Stress Corrosion. In stress-corrosion research it was found that some plastic deformation must take place in a magnesium alloy before stress-corrosion cracks can develop. Cracking probably does not occur in those crystals which are favorably oriented for slip to occur, but it does take place in those crystals which are resistant to easy plastic deformation. This work was partially supported by the Corrosion Research Council and the Atomic Energy Commission.

Heat Effects of Electrochemical Processes. The various heat effects that are associated with electrochemical processes are being investigated calorimetrically at the request of the Atomic Energy Commission. This work is concerned with the measurement of the enthalpy change (ΔH) of electrochemical reactions, and with electrode polarization and complex equilibria in solution. Another study of the entropy change (ΔS) of half-cell processes, dealt with the entropy of ions in water solution and with transport processes in electrolytic cells. The heat effect caused by the passage of an electric current across the interface between two electrolytes is also being investigated.

Research with Molten Salts. In an earlier program to provide basic data on the electrochemistry of molten salt systems, a new type of reference electrode employing a sodium ion conductive porcelain, was developed. In further work this year, a similar porcelain was found suitable for the electrodes in a cell used for measuring the transference numbers of molten sodium nitrate. It was also found that similar porcelains can be made that are conductive to other monovalent ions, when in contact with a corresponding melt. Another fused salt project in progress consists of a study of complex equilibria by means of high-temperature calorimetry.

Rotating beam fatigue-testing equipment used to study the effect of various components of the atmosphere on the fatigue properties of metals. Studies in controlled atmospheres show that fatigue is profoundly affected by the environment at the surface of the metal (page 98).

Mechanism of Metal Deposition Studied. The mechanism of electrodeposition is the subject of two experimental investigations, one on the mode of growth of copper crystals, and the other on the phenomena occurring when a metal is deposited by microsecond pulses of current. The growth of crystals is being studied by electrodepositing copper on isolated faces of single crystals and examining the topography and structure of the deposits by metallographic methods and X-ray diffraction.

In this work valuable information is being developed on the relationship between the conditions of electrodeposition, the crystal face on which the

deposition occurs, and the mode of growth of the deposit. Under some conditions the deposit has a single crystal structure and appears as a continuation of the seed crystal. Under other conditions the deposit may start as a single crystal and gradually become polycrystalline with time, or—as a consequence of topographic features—it may form as a single crystal with boundaries parallel to the direction of growth.

Preliminary experiments with extremely short pulses of current show that copper deposits from a sulfate bath at high current efficiency with current pulses of one microsecond, but that efficiency decreases with shorter pulses. During a single pulse of about one microsecond duration, at a high current density, a deposit of copper in the form of a dendrite was formed. An extended study of the characteristics of deposition of metal with short pulses of current is expected to contribute information on the mechanism of electrode reactions and deposit formation.

Electrodeposition from Organic Solutions. Aqueous solutions are not suitable for electroplating on chemically reactive metals such as uranium if the coating is to be strongly adherent to the substrate. A study, partially supported by the Atomic Energy Commission, was therefore undertaken to investigate the electrodeposition of metals from organic solutions. Although the problem of coating adhesion was not completely solved, sound coherent coatings of zinc and of copper were obtained from solutions of their respective salts in formamide. Under suitable conditions, coatings could be easily built up to several hundred microns in thickness. It was also found that tin could be readily electrodeposited from dimethylformamide solutions of stannous chloride. None of these deposits, however, formed as smooth coatings. Instead, they grew in the form of large ductile crystals which were shown to be single crystals by X-ray diffraction.

2.2.5 ORGANIC AND FIBROUS MATERIALS

Research on the properties of organic and fibrous materials covers both natural and synthetic polymeric structures. To gain a better understanding of the relationships between the composition and the properties of polymers, studies are being conducted on rubbers, textiles, papers, leathers, plastics, dental resins, and related materials. The properties of polymers depend upon the size, shape, distribution, and flexibility of their molecules, and on the interactions of the molecules with each other. A more basic knowledge of their fundamental properties and improved measurement techniques are necessary for the development and efficient utilization of these materials.

During the past year fundamental studies were made of the kinetics of crystallization, the melting temperatures of crystallites, the nature of free radicals formed in gamma-irradiated polymers, the thermal stability of polymers exposed to a temperature of 1,200 °C, and the polymerization induced by ionizing radiation of monomers confined under high pressure. The propagation of strain waves in fibers subjected to high-velocity tensile-impact loading was investigated as well as the energy-erosion relationships

involved in collision of meteorites with potential spacecraft structural materials. Chemical studies included vulcanization-type reactions, chrome-vegetable tannages, and crosslinking mechanisms and effects on properties of synthetic fibers. Analytical methods were developed for alum-coagulated styrene-butadiene rubber and for 5.6-dichlorobenzoxazolinone to be used as a mildew-preventive in leather. Hydrogen bonding in calcified tissues, the dimensional stability of resin dentures, and particle size and shape effects on strength of amalgam alloys were investigated.

New Method for Analyzing Synthetic Rubber. The extraction procedure generally used for the analysis of alum-coagulated styrene-butadiene rubber gives low results for organic acid, probably because of interference from aluminum ions which tie up some of the organic acid. A procedure was therefore devised for preventing this interference by preferentially reacting the aluminum ions with 8-hydroxyquinoline, and thus freeing the total organic acid for titration. The technique employs meta-cresol purple as an indicator to distinguish the organic acid from the mineral acid formed in the reaction. Both the reaction and titration are carried out in an organic solvent suitable for dissolving the rubber. With the use of only a single weighed sample, the procedure may be adapted to the determination of other gross constituents of alum-coagulated SBR.

Nylon fiber (above) develops helical coils (below) after chemical treatment. Such artificially induced structural changes may lead to fibers which will resist extreme environmental conditions (page 102).

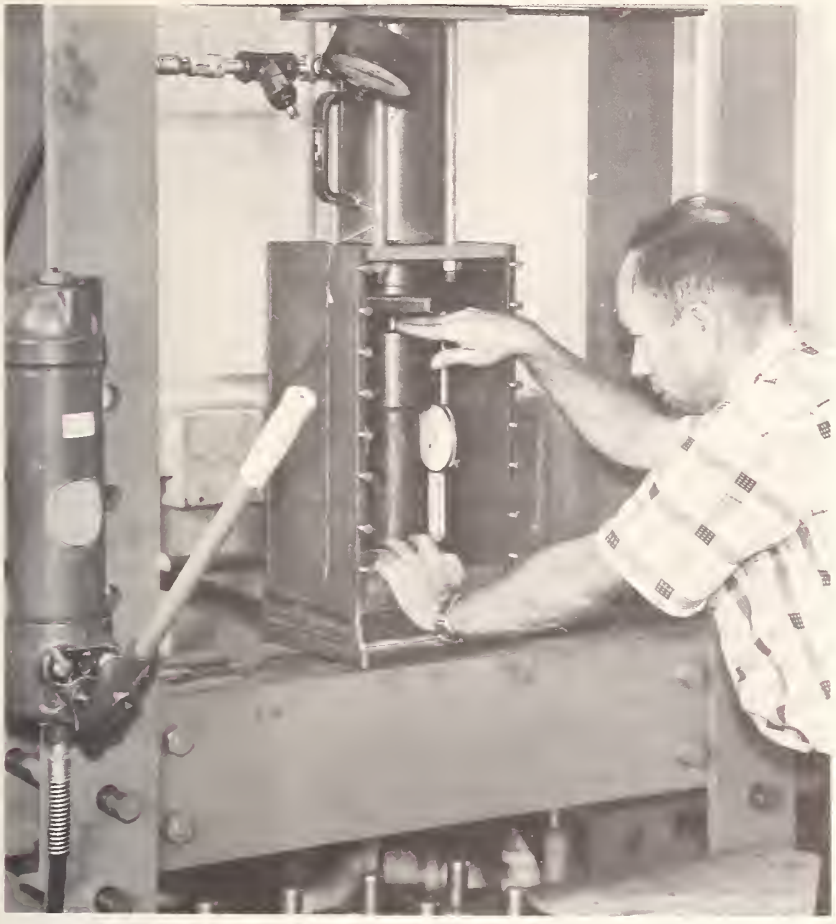
Model Compounds Used in Vulcanization Studies. Natural rubber reacts with sulfur and organic accelerators in the normal vulcanization process, but details of the reaction are obscure. Apparently double bonds are necessary, since the reaction does not occur with hydrogenated rubber. Studies of the reaction of sulfur, hydrogen sulfide, and accelerators with two simple model compounds, one a propylene containing one double bond, and the other, a butadiene containing two double bonds, showed the formation of sulfides, disulfides, and carbon-to-carbon bonds. Butadiene with its conjugated double bonds served as a model compound for the conjugated system formed in the vulcanization of rubber. A dithiocarbamate accelerator was found to facilitate the formation of hydrogen sulfide and then to promote the reaction of hydrogen sulfide with propylene or butadiene. Some reactions included the formation of compounds from free radicals originally present. Appreciable portions of the products were nonvolatile.

Crosslinks Determined in Anisotropic Fibers. The Flory-Rehner theory of isotropic swelling of rubber crosslinked in the dry state was extended to an anisotropic system crosslinked (short crosslinks) in the dry, oriented state. The new parameters introduced into the equation were readily determined from dimensional changes of the fiber in a suitable solvent using a photomicrographic technique. With this technique swelling equilibrium can be attained within 30 minutes. In the study, surprisingly good agreement was found between the equivalents of crosslinks calculated from swelling measurements and from chemical analyses.

Impact Loading of Fibers. In many civilian and military applications the performance of textile materials subjected to high rates of strain by impact loading is not well understood. An investigation was therefore made of the behavior of representative textile yarns subjected to impact loading at velocities of 150 ft/sec in which Von Karman's concept of critical velocity (that velocity at which a filament breaks immediately upon impact in tension) was extended and applied. In the study, critical velocity estimates were arrived at, ranging from 400 ft/sec for glass fibers to 950 ft/sec for nylon and some high strength rayons.

Mechanism of Retannage Studied. A combined chrome-vegetable tannage not only converts hides more rapidly into leather than a single tannage but the combination improves abrasive wear and tannage stability. Recent work showed that a reaction, probably of the chelate type, occurs between chrome and the vegetable tannage, and that the affinity of the substrate for tannin is at a peak when 2.5–3.5 percent of a chromium complex (percentage calculated as chromic oxide) is present. Experiments indicated that a copper compound gave results similar to those obtained with chromium. It therefore appears that other metallic salts may be developed for future uses in combination tannages.

Synthetic Fibers Structurally Modified. To provide basic information for the development of structurally modified fibers that will resist extreme environmental conditions, the Bureau conducts fundamental research on the properties of synthetic fibers. In this program, efforts are made to correlate the chemical properties, heat and radiation resistance, and polyelectrolytic



Polymers have been produced from materials, such as carbon disulfide and nitrogen, which do not form polymers under ordinary conditions. A combination of high pressure and subsequent exposure to intense gamma radiation was used to induce polymerization (page 104).

behavior of structurally modified fibers with size, number, and kind of crosslinks and grafts in the polymer fibers.

In preliminary investigations, unexpected crimping and helical coiling occurred when solid nylon-6 homofibers (homogeneous one-component fibers with round cross sections) are treated with a swelling agent and disulfide and poly(methylene sulfide) crosslinks inserted while the fibers are in the swollen state. Subsequent crimping in the dry state is attributed to heterogeneous crosslinking. Helical coiling occurs when the crimped fibers are treated with a strong swelling agent which completely destroys the remaining crystallites.

Polymer Crystallization Studied. Although thermodynamic equilibria can be applied to the crystallization and melting of polymeric materials, these large molecules behave somewhat differently from small ones, partly because they never become completely crystallized. If crystallization of

high molecular weight polymers takes place at temperatures below the equilibrium melting temperature, the resulting crystals will melt at a lower temperature than if they had formed nearer to the equilibrium temperature.

In a recent study, an equation was developed that gives a mathematical relationship between the melting temperature of a crystallite formed at non-equilibrium temperatures, the equilibrium melting temperature, and the temperature of crystallization. This relationship was found to agree very well with experimental values obtained from studies of the crystallization and subsequent melting of rubber under nonideal conditions.

A theoretical study of polymer crystallization mechanisms revealed that crystallization rates and isotherm shapes are sensitive to small amounts of structural irregularities in a polymer chain. This behavior results from a compositional change in the melt, which causes a marked decrease in the nucleation rate during crystallization. The theoretical conclusions, which were confirmed by experimental observations, indicate that chain irregularities as little as one mole percent should be detectable.

High Pressure Polymerization. Many molecules that have double or triple bonds in their chemical formulas—for example, carbon disulfide and nitrogen—do not form polymers under usual conditions. In general, when attempts are made to polymerize such molecules, the chemical equilibrium favors monomer instead of polymer production. However, if very high pressures are applied, the equilibrium will be displaced to favor polymerization. Reaction can be initiated by heat, catalysts, or ionizing radiation. In work for the Office of Ordnance Research, materials were placed under pressure in a bomb and exposed to gamma radiation. When irradiated, perfluoroheptene polymerized to a moderate degree, whereas when unirradiated, no polymer formed. At 10,000 atm, 50 °C, and under irradiation, carbon disulfide formed a polymer which was previously obtained only at 50,000 atm and high temperature.

Thermal Stability of Polymers. The relationship between thermal stability and molecular structure of polymers was investigated at pyrolysis temperatures up to 1200 °C. In this program, sponsored by the Air Force, polymers which are originally highly crosslinked—such as polytrivinylbenzene and phenolic and epoxy resins—and polymers which develop crosslinks at the pyrolysis temperatures—such as polyvinylidene fluoride and polyacrylonitrile—were observed to yield carbonaceous residues and low molecular weight volatile fragments. When polymers which do not become crosslinked—such as polystyrene, polymethylene, and polytetrafluoroethylene—were heated to pyrolysis temperatures, only volatile products of low molecular weight were noted. In either case, the higher the temperature, the greater is the fragmentation of the degradation products. This research has yielded additional proof that the energy-absorption capacity of a polymer during thermal degradation is inversely proportional to the molecular size of the volatile fragments. Furthermore, it has demonstrated that polymers which leave a carbonaceous residue and liberate gases at the elevated temperatures generally give superior ablation resistance in missile nose cones.

Free Radicals in Polymers. Free radicals can be observed, estimated quantitatively, and sometimes identified in very small amounts by electron spin resonance spectroscopy. As part of a program sponsored by the Air Force to investigate the reactions of free radicals in polymeric systems, a number of polymers, including polystyrene, cellulose, and fluorocarbon polymers, were irradiated and examined. Considerable new information was obtained on the mechanism of polymerization and on the chemical changes induced in these polymers by ionizing radiation. In addition, fluorocarbon monomers were observed to yield appreciable amounts of free radicals when irradiated at liquid-nitrogen temperatures.

Fungicidal Analysis. A study was undertaken to find a means for determining the quantity of 5,6-dichlorobenzoxazolinone in leathers. This compound is used as a fungicide to prevent mildew in leather, and an analytical technique was required by the Office of the Quartermaster General for treatment control. A colorimetric method was devised which consists of the conversion of 5,6-dichlorobenzoxazolinone to 2-amino-4,5-dichlorophenol by alkaline hydrolysis, diazotization of the aminophenol, coupling with resorcinol to give a colored azo compound, and photometric measurement of the color. A chloroform-water mixture is used to extract the fungicide. Vegetable tannins which would interfere with color measurements are precipitated with lead acetate and removed in the aqueous phase of the extract which is discarded. The interfering effect of chromium is also overcome, either because the water in the mixture prevents formation of a chrome-fungicide complex, or because the chrome itself is removed in the aqueous phase.

Meteorite Erosion of Materials. The possible hazard of meteors to the space-craft of the future has recently been made more significant by the discovery of a charged zone around the earth which attracts meteoric particles. When small masses, traveling at the velocities at which meteors travel, collide with solids, the transformed energy is so large that both the projectile and the target in the immediate vicinity liquefy after collision. The extent of this meteorite-erosion hazard is being investigated, in research sponsored by the Air Force, by examining the craters produced in collisions of liquid drops with liquids, and in collisions of metal spheres with metal plates, at velocities up to 20,000 ft/sec. An equation was derived relating the maximum depth of the cavity produced in a target liquid as a result of collision with a liquid drop, to the kinetic energy of the impinging drops.

Calcified Tissues Investigated. Hydrogen bonding in calcium-deficient apatites was investigated by infrared spectrophotometry in work supported in part by the U.S. Public Health Service. A direct correlation was found between the number of calcium ions missing per unit cell volume, obtained by chemical analysis and refractive index measurements, and the hydrogen bond content.

Dimensional Changes in Dentures. A study sponsored by the American Dental Association and the Federal dental services established that the dimensional changes of dentures in service are too small to be of clinical significance. In the investigation more than 200 dentures were

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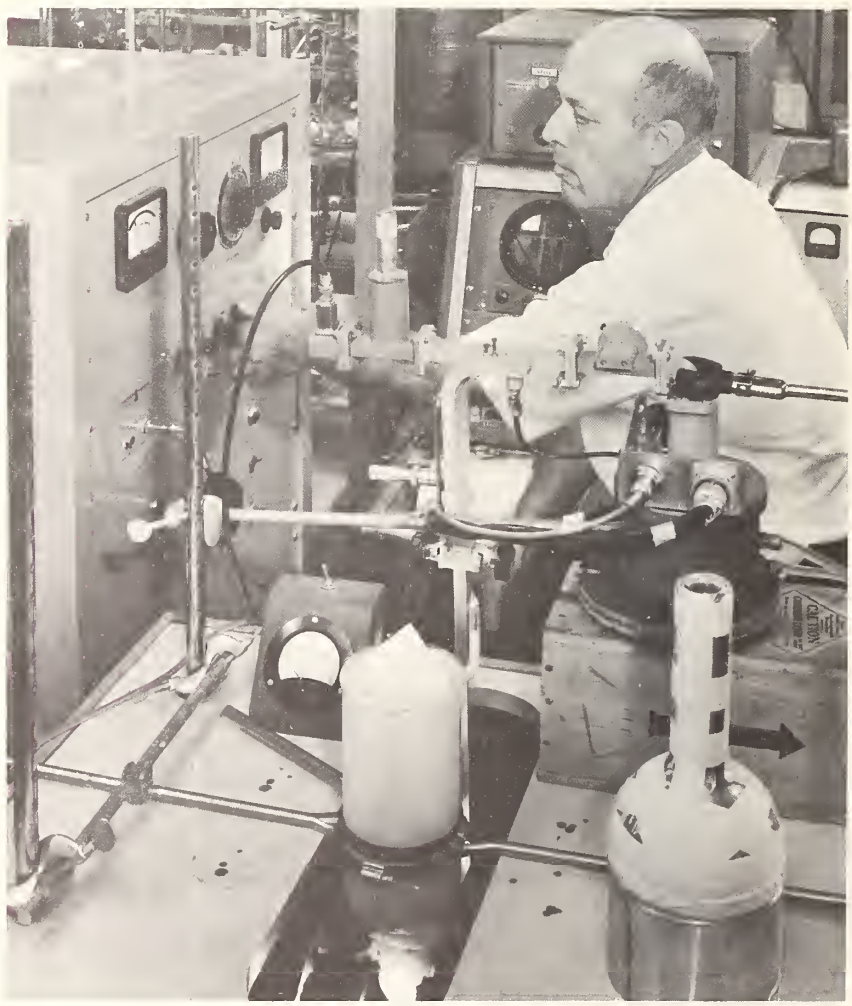
measured, some over a period of six years. They had been made of 12 different types of polymers processed by a variety of currently used methods. Acrylic resin dentures processed with simple conventional equipment, employing compression molding, were just as accurate and as dimensionally stable as dentures made with other types of resins using complex and costly equipment.

Dental Amalgams from Spherical Particles. The particle size of the alloy (Ag-Sn-Cu-Zn) used in making dental amalgams was investigated, independently of other variables, in a study sponsored by the American Dental Association and the Federal dental services. A standard alloy com-



Data were obtained on the mechanism of polymerization and on the chemical changes induced in polymers by ionizing radiation. Here free radicals produced by ultraviolet radiation are studied by electron spin resonance (page 105).

position was used in the form of spherical particles produced by spray atomization. The particles were separated into eight different sizes, the smallest 1–4 microns and the largest 105–150 microns in diameter. Particles from 15–50 microns diameter exhibited the highest strength of all those studied. The study showed that an alloy in this spherical shape produces an amalgam equal or superior to those in current use, and offers a new approach to the control of critical amalgam properties, such as early strength, setting time, and flow, and promises major advances in the simplification of manufacture.

2.3. SPECIAL TECHNICAL SERVICE PROGRAMS

2.3.1. APPLIED MATHEMATICS

The Bureau's applied mathematics facility conducts basic and applied research and renders advisory services in various mathematical fields. These services are available to other Government agencies as well as to the Bureau's staff. Modern computing equipment is used by the facility in support of its program.

During the past year the Bureau emphasized activities in statistical and numerical analysis, mathematical physics, and operations research. Extensive assistance was rendered in these areas and in digital computation. Special attention was given to problem formulation and analysis in order to select and develop numerical methods for the solution of problems in engineering and the physical sciences, utilizing both automatic and non-automatic computing machines. An appreciable share of the mathematical program was devoted to government problems of business management and operation, sometimes called data-processing problems. Significant progress was achieved in the exploration of the utility of modern digital computers in the mechanical translation of scientific publications, for which there is a continuing urgent need.

As in previous years, the Bureau's applied mathematics program was strengthened by the active interest and support of other Government agencies. The Office of Naval Research and the USAF Office of Scientific Research supported fundamental and applied research in numerical analysis and mathematical physics, respectively. The National Science Foundation continued to support the compilation of a handbook of mathematical functions and mathematical research related to information retrieval. The study of mechanical translation of scientific publications was supported by the U.S. Army Research Office and the Office of the Chief Signal Officer, U.S. Army.

Combinatorial Analysis. Work continued in combinatorial analysis, a branch of mathematics concerned with the arrangements of finite sets of objects. It was applied to the selection of the best pattern of linkages in transportation or communication networks, in the determination of the most efficient method for encoding messages to provide automatic correction of

possible transmission errors, and in the design of experiments to maximize the useful information obtained from a given number of measurements.

Eigenvalue Theory. The determination of eigenvalues for operators is a central problem in mathematical physics which frequently involves considerable numerical difficulty. A method of "generalized special choice" has been developed for determining lower bounds to the eigenvalues of self-adjoint linear operators. Numerical results carried out for the anharmonic oscillator are satisfactory even when perturbation theory fails. The method has also been used to estimate the eigenvalues of the spheroidal wave equation. The numerical results obtained by this method were found to be excellent in regions where difficulties were experienced with other procedures.

Matrix Theory. Various schemes were investigated for the solution of matrix eigenvalue problems. Extensive research continued in the development of techniques for obtaining the characteristic roots, the determinant, and the P-condition number of matrices. Several new results in doubly stochastic matrices have been obtained through the exhibition of the permanent as an inner product in a suitable space. Inequalities were derived which lead to new bounds for the determinants of nonnegative Hermitian matrices.

Approximation Theory. Research in approximation theory was emphasized because of its fundamental importance in numerical analysis. Extensive investigations of best approximation by nonlinear families were continued. A study was conducted concerning the approximation to convex functions by means of convex polynomials and trigonometric polynomials. The results contain some explicit constructions and estimates of accuracy. Tchebycheff approximation by rational functions was investigated, with emphasis on the computational aspect. Significant research on infrapolynomials and their generalizations was also performed.

Numerical Experimentation. In areas of numerical analysis where no theory exists or existing theory is merely suggestive, numerical experimentation may provide insight into a method of problem solution. Such experiments were performed in the numerical solution of nonlinear partial differential equations. The partial differential equation determining the pressure distribution in a gas-lubricated bearing was studied. The final aim, once a method of solution was found, was to compute a set of design curves for such bearings. Also, a system of three nonlinear, ordinary differential equations arising in a study of the internal structure of stars was investigated.

Machine Translation. Further progress was made on the automatic Russian language translation scheme being developed by the Bureau. In contrast with other machine translation projects, the Bureau project is characterized by emphasis on syntax in the conventional sense and by a system of predictions. A Russian word in a sentence "predicts" certain other grammatical forms; for example, a transitive verb predicts a direct object.

A significant innovation has been the development of a procedure called "profiling," by which clause and phrase boundaries are recognized mechani-

cally before the detailed analysis by use of predictions begins. This technique will greatly increase the speed of translation through the proper placement of subject and predicate in the syntactic analysis.

Mathematical Tables. The main concentration in mathematical tables during the year has been on the completion of the Handbook of Mathematical Functions. All chapters of the Handbook now exist in manuscript form. A modest amount of revision of expository text and updating of bibliographies remain. The Chapters in press comprise about one-quarter of the volume.

Digital Computation. Digital computers were applied in both the scientific and data processing fields. Scientific computing was centered about measurement and calibration, i.e., primarily concerned with problems on gage blocks, thermometers, bead sizing, heat pump capacity, transistor aging, etc. Problems such as those arising in studies of crystal structure, the thermodynamic properties of gases, spectrum analysis, and colorimetry also required extensive computing techniques. Significant computations were performed on problems related to radiation patterns of antennas, light scattering, heat transfer in crystals, and the radiative envelopes of model stars. Important problems in data processing included the assignment of radio frequencies, traffic studies, mathematical investigations related to postal operations, analysis of electrocardiograms, airline traffic surveys, and the simulation of military engagements.

Extensive research was continued in the field of automatic programing, where the primary objective is to render easy, fast, and inexpensive communication between electronic computers and human users. The Bureau pursued this objective with direct practical applications as well as through research and long-range development. The Black Box Computer—a tool devised to speed a problem from originator to machine—was improved and its applications expanded. By use of this tool, Bureau laboratory workers can prepare their problems for direct introduction into electronic computers to produce least-square fits, numerical integration and interpolation, compilation of physical tables, evaluation of certain desired statistics, such as the mean or the standard deviation, etc.

The Bureau has performed research in the area of artificial languages and their translation by machine. It participated during the year in the establishment of programer-oriented languages—ALGOL for scientific applications and COBOL for business or data-processing problems. Significant contributions were made, also, to the program on standardization of symbols, languages, and equipment of the Office Equipment Manufacturers Institute.

Experiment Designs. Work on the mathematics of experiment design resulted during the year in the substantial revision and preparation for publication of the "catalog" of fractional factorial designs for the 2^m3^n series developed during the preceding year in preliminary form. A special class of "weighing" designs of the fractional factorial type was studied. These designs approach the classical weighing designs with respect to the small numbers of observations required, but still permit identification of

two-factor interactions and thus are particularly appropriate for use in experiments on the determination of fundamental physical constants. In addition, they are applicable to the evaluation of routine calibration and testing procedures. Explicit construction and "cataloging" of a series of magic rectangles for use as trend-elimination designs were accomplished. These rectangles provide orders for running the "treatment" combinations in a two-way classification so that comparisons of the resulting "main effects" of the respective "treatments" are not upset by linear trends or drifts in the measurements. A special operational calculus for symmetrical and asymmetrical factorial arrangements was developed.

Life Testing and Reliability. The intensive investigations of the measurement of reliability conducted by the Bureau were summarized to show the possible weaknesses of current life-testing procedures being applied when the assumptions on which they are based are not valid. New and improved results were obtained, including excellent approximations to the distribution of a sum of Weibull-distributed random variables and to the OC-curves and average-sample-size expressions for sequential tests based on sums of Weibull-distributed random variables.

Probability and Mathematical Statistics. Studies in probability and mathematical statistics took various forms. Work was resumed on the NBS tables of power points of the noncentral F- and χ^2-distributions. A detailed numerical investigation was initiated of properties of a special family of probability distributions derived from the uniform distribution on (0, 1) by a transformation suggested by J. W. Tukey. Information theory was applied to the analysis of a four-way contingency table. The fourth in a Bureau series of selected bibliographies of statistical literature for the period 1930–1957 was completed.

Mathematical Physics. Research in mathematical physics emphasized the formulation of mathematical theories basic to the development of theoretical physics and engineering science. Investigations included research in the kinetic theory of plasmas and magnetohydrodynamics, in which the previously developed theory for homogeneous plasma was generalized to include the long-range collective behavior, the effect of memory in oscillations, and the expansion wave problem in neutral gases.

Investigations concerning satellite orbits were continued. Emphasis was placed on the central problem of satellite astronomy, namely, the determination of the motion of an artificial satellite around an axially symmetric but oblate planet. The method developed reduces the relevant Hamilton-Jacobi equation to separable form, and provides for the application of well-known techniques in successive approximation to the problem of satellite motion.

Other work in mathematical physics included studies of Brownian motion, as governed by the Chapman-Kolmogoroff functional equation; elliptic boundary-value problems, in which important bounds for the deflection of elastic plates were derived; the deflection of circular plates with radially varying thickness under a radially symmetric traverse load and edge conditions; and the flexure of elastic beams.

Operations Research. General areas of investigation during the year included game theory, graph theory, weapon simulation. Boolean functions, and mathematical models of distribution networks.

The problem of optimal frequency allocations for a network of radio transmitters is similar to that of finding a minimum point-cover of a linear graph. Graph-theoretic algorithms were investigated. A significant development was that of a general algorithm, suggesting characterization for optimal coverings of a set, providing promising alternatives to known algorithms, and specializing to the minimum point-cover problem.

Three major areas were explored in connection with the analysis of mathematical problems related to postal operations. These areas were: (1) a long-range study of mathematical models of distribution networks, with a view to optimizing the location of distribution centers and the degree of system centralization; (2) determination of the appropriate parameters for a specified mail-sorting device; and (3) studies concerning procedures in existent, partly automated post offices.

Other significant activities in operations research during the year included the analysis and computer simplification of Boolean functions (important in network and circuit theory), the analysis and simulation of missile system operation, a study of optimal radar site distribution, and the analysis and simulation of electronic countermeasures.

2.3.2. DATA PROCESSING SYSTEMS

The Bureau has been conducting a broad program of research and development in analog and digital technology and in application techniques needed to foster effective use of data processing systems by the many agencies of the Government. A major purpose was to extend the areas of application beyond conventional "paperwork" as well as to expedite the data handling problems of the experimental sciences and the storage, search, and retrieval of information. The Bureau's data processing systems laboratory acts as a centrally available technical facility for providing assistance and advisory services for such purposes within the Bureau and to other government agencies.

Some present areas of activity include research, design, and evaluation of improved circuitry; logical organization of data processing and control systems; automated collection, transmission, and presentation of experimental data; and techniques for machine processing of syntactic and graphic forms of data. Of particular significance is the continued expansion of the program of assistance to the Bureau's own research laboratories in identifying problem areas particularly adaptable to automatic data processing techniques and demonstrating the feasibility of preparing experimental data in acceptable form for input to and output displays from a central high-speed automatic data processing facility. The range of data processing applications both for NBS and for other government agencies increased materially during the past year.

The PILOT data processor, now nearing completion, will provide a highly flexible research facility for new and unusual Government data processing problems (page 112).

PILOT Data Processor. The engineering design and physical structure of the NBS PILOT Data Processor, a highly flexible research tool developed for investigating new and unusual data processing problems for the Government, was completed. Power distribution, clock distribution, circuit protection, and logical wiring for all parts of the machine were installed. The secondary diode-capacitor memory is already functioning as a part of the PILOT system, while the completed primary diode-capacitor memory is ready to be mated to the central machine. Performance tests were completed on the logical wiring of the system and on 7,000 individual stages of the system.

The peripheral equipment presently attached includes an automatic typewriter, magnetic wire handler, magnetic tape handler, and high-speed paper tape reader. Initial service programs were prepared, and specifications were established for the preliminary compiler for the main computer. The first set of training courses in both programing and maintenance and operation was conducted in preparation for routine operation.

Technical Assistance for Data Processing. The continuing aid and assistance to the laboratory operations throughout the Bureau led to the identification of a considerable number of potential areas for automatic data recording and processing, many of which had special data-conversion problems. Technical assistance was provided through study of the problem to determine whether analog and/or digital techniques were applicable and

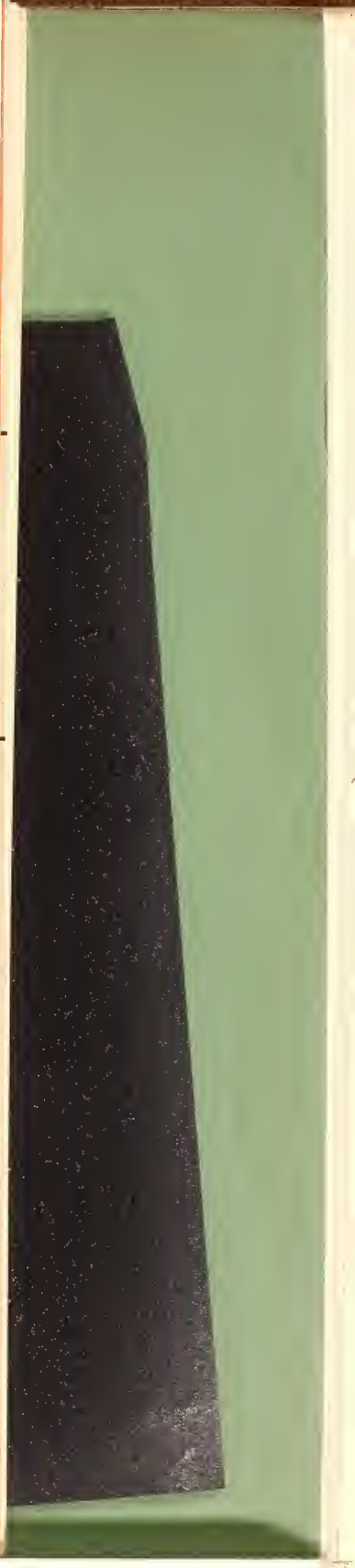
through demonstration of the feasibility of such applications. Additional assistance was given in the form of design and development of special data-logging equipment, some of which was constructed by the "user" laboratories with advice in the utilization of packaged circuitry provided by the data processing systems laboratory in order to convert the data to input form acceptable to the computer.

Typical problems on which assistance was provided included gas analysis by infrared spectrometry, plasma traverse, transmission of data from radiation physics, coulometric titration, heat transfer by radiation, concentration of near-saturated solutions, separation of signals from noise, radial distribution of plasma properties, search of atomic nuclei in crystal structures, model loop for process control with dead time, stability constants of complex ions, nuclear reactor transients, probability of convoluted probability functions, theory of reflection from metallic surfaces, processing metallurgical photomicrographs, plotting of continuous curves by interpolation of discrete data on magnetic tape. storage and examination of 1,000 points in the focal plane of a lens. and handling of data from an electron paramagnetic resonance unit.

Components and Techniques. The development of faster, more complex, and more reliable computers and data processors has led to the study of new components and further investigation of existing ones. Measurement of the properties of these components is fundamental. Several significant contributions were made to the theoretical analysis of solid-state semiconductor devices operating as circuit elements.

A large-signal junction transistor equivalent circuit and switching theory study was completed. This study produced a new large-signal junction transistor equivalent circuit that is valid for all modes of circuit operation. The physical charge-concept approach to semiconductor devices was bridged mathematically to the area of device application, resulting in nonlinear differential equations that could be solved by graphical, analytic, and computer techniques. These equations made possible analytic solution of modes of junction transistor operation which were previously untractable. The use of new time domain measuring techniques was incorporated into the study as a means of evaluating elements of the equivalent circuit. The study also resulted in a characterization of the transient input base current of the junction transistor for all driving conditions. The static base-to-emitter voltage-current characteristic and a unique time constant factor were shown to be the principal data required for the large signal switching analysis.

A tunnel diode large-signal simulation study was undertaken which involved the development of an analytic approximation to the static voltage-current characteristics of the tunnel diode that displayed the required negative-resistance region. A complex second-order nonlinear differential equation and techniques for its solution by analog computer and graphical analysis methods were developed. These equations are of considerable value in determining the large-signal switching response of the tunnel diode in digital circuitry.



The investigation of high-speed transistor flip-flop circuits was initiated. Several basic configurations such as current-controlled, collector-clamped (nonsaturating), and saturating types are under investigation.

Research was continued in determining the relation between properties of films which show promise as very fast memory and switching elements and their structure and chemical composition. Major effort was devoted to developing a fast transmission line magnetization reversal tester and an accompanying sampling oscilloscope system, perfecting the thickness-measuring techniques, and making microchemical analysis of the films. The test set-up for measuring the fast magnetization reversal consists essentially of a parallel-plane transmission line or wave guide operating in the TEM mode.

Experimental study of the high-speed partial switching behavior of ferrite memory cores for use in the design and development of improved digital circuits in advanced digital computing and information-handling systems and for performing switching and memory functions was continued. A report covering the mathematical analysis of a transistor-magnetic-core digital circuit was completed. The concepts and analytical methods presented in this report have general application in the design of very high speed digital circuits.

Automatic Data Retrieval. Under the sponsorship of the Patent Office and the National Science Foundation, investigation continued leading to the development of automatic programing systems for processing information contained in collections of documents, through syntactic analysis of both natural language text and associated pictorial information. A sequence of grammars was written for a fragment of English concerned with simple pictorial subjects. Programing procedures were developed that enable a linguist to test the grammars for adequacy by producing samples of sentences with their assigned syntactical analyses. In addition, theoretical models for language grammars and for picture-processing mechanisms were explored by both simulation and analytical study. Results from automata theory were applied to classification of the grammar model used in the linguistics research, and mechanical-theorem-proving literature was searched for results usable for formal inference in the development of a general-purpose research tool, such as a Picture Language Machine, which will provide the capability for exploring more complex problems in pattern recognition and linguistic analysis.

Development of Information Selector. The design of an improved model of an information selecting device for retrieving information from large files of documents stored on coded microfilm was developed for the Navy Department's Bureau of Ships. This new model of the rapid selector provides increased speed and reliability, simplicity of film handling, multiword selection, and programed logic control of output. An improved input preparation device for producing original coded master film was also developed as part of the system.

Special-Purpose Digital Computer (AMOS IV). Under a program sponsored by the Weather Bureau, a special-purpose digital computer,

AMOS IV, was developed as the central element in an automatic weather station to collect and reduce weather data prior to transmission. During the past year this prototype has undergone extensive testing and modification. A number of diagnostic routines were written and checked on the machine; circuitry for pre-processing signals of the variety produced by weather-sensing elements was developed and tested insofar as practical; an oscilloscope was added for displaying the contents of any memory channel and for displaying characters or graphical information; and new circuitry for counting against a variable time base was included for versatility. In addition, a closed circuit teletype line was established between the NBS laboratory installation and the Weather Bureau, with low-speed printers connected at each end. Several low-speed messages were transmitted over this line. The Weather Bureau began constructing additional machines similar to the AMOS IV, under NBS technical guidance. Training of Weather Bureau personnel in the use of digital and transistor circuitry and in computer programing has continued in conjunction with the system development.

Data Source Automation. An automatic data-recording system was developed for the Navy Bureau of Supplies and Accounts in connection with the preparation of Naval supply messages for ordering Federal stock items. The envisioned system consists of the format control and preparation of messages for teletype transmisison on punched paper tape, and catalog item selection and transcription of descriptive catalog information. The initial system will contain an operator's panel for hand selection of the variable information with visual display of message before printing out. The objective is to minimize the number of errors in the Navy supply system originating in the initial process of ordering stocks. The supply catalogs contain approximately one and one-quarter million items in 76 major categories printed on one-quarter million pages.

Weapons Systems Evaluation. Under the sponsorship of the Bureau of Naval Weapons, continuing assistance was provided on computation, simulation, and data processing problems as applied to weapons systems evaluation and test range instrumentation for the Pacific Missile Range. A study was completed of the real-time computation system to provide on-line computation of test missile trajectories, some vehicle control functions, and tracking acquisition aids for remote tracking installations with extremely fast repetitive computations of impact points for range safety purposes. This study led to the preparation of specifications, evaluation of initial phase designs submitted by contractors, and review of the final multicomputer design. In addition, an advanced flexible system was planned for handling various types of multichannel telemetry inputs either on-line or post-flight, at very high speed with computer control of data format, location, and sampling rate. This was a cooperative effort with the Naval Air Development Center.

Attention was also directed to methods of specifying performance of very fast, very accurate analog-digital conversion systems and the necessary lab-

oratory instrumentation for measurements. A facility for very high accuracy static measurements was established, and three production types and one developmental type of analog-to-digital converter are being evaluated.

Airways Systems Analysis. Detailed studies of the information content of a future air traffic control system utilizing large-scale automatic data processors were continued under Federal Aviation Agency sponsorship. Preliminary design specifications of the display and control requirements for an adaptive controller-equipment module (CEM) were developed. Concurrent with logical design studies, hardware implementation of a breadboard system was planned and initiated.

Pictorial Data Processing. Under the sponsorship of the Naval Training Device Center, research efforts were continued in developing methods and techniques for scanning aerial stereophotographic information and, in writing computer programs, for translating this information into elevation profiles. A three-dimensional model with relatively small black and white areas was photographed, scanned, and transcribed into SEAC; and computations of altitude and planimetric position were made that were within the accuracy of the scanner resolution. In addition, processes for the removal of objects outside the given overlap regions and for producing outlines have been coded. The programs for deriving photogrammetric data from pictures containing relatively large areas will continue to be investigated in the hope that similar, possibly identical, programs will be applicable to continuous-tone photographs after image processing.

Psychological Data Processing. The system previously developed at the Bureau for processing electrocardiograph data was redesigned to meet the need of the Air Force Office of Scientific Research for a low-cost system for processing psychological data. As finally constructed, the new system provides for scanning and recording ten analog voltages in digitized form on magnetic tape. In addition, a translator is provided to change the output from binary to binary-coded decimal. This experimental equipment was sent to the University of Georiga, where it will be put into operation.

Data Processing Applications. The mechanized NBS personnel data recording and reporting system, including file maintenance and the production of 44 regularly recurring personnel reports and one budget report, was put into routine operation. Several new reports were added to the system and approximately 15 special on-request reports were also generated during the year. Several other government agencies have expressed considerable interest in the project (Tennessee Valley Authority, Railroad Retirement Board, General Services Administration, Bureau of the Census).

The feasibility study for determining the applicability of automatic data processing techniques to certain operations of the Federal Communications Commission was concluded. Assistance was given to the Public Health Service in developing mechanized collection of information on radiological hazards from food and water supply, medical and dental diagnosis and therapy, atmospheric fallout, industrial and research laboratories, and other

sources, including catastrophic release of hazardous radiation. The Division of Radiological Health, Public Health Service, was given assistance in analyzing equipment and methods to be used in the determination of the amounts of specific radioisotopes from the gamma-ray spectrum readings obtained on food samples. In addition, equipment was designed and constructed for collecting data from a gamma spectrum analyzer along with identifying comments from a manual keyboard. It is planned to use this same equipment to provide on-line operation of the gamma spectrum analyzer with an electronic computer.

A final report was submitted to the Research Grants Division, National Institutes of Health, in connection with a preliminary study of the applicability of automatic data processing methods and techniques to more effectively maintain and select information concerning their research grants program.

The Public Housing Authority constantly reviews a tremendous volume of reports of eligibility for continued occupancy of low-rent housing. Continued advice and assistance were given in programing, debugging, and running various statistical routines.

Under the sponsorship of the Interstate Commerce Commission, an exploratory investigation was initiated of the major objectives, functions, and operational units of ICC to determine feasibility of applying automatic data processing techniques to selected activities and operation. Several short-range projects and several long-range tasks with substantial potential gains in effectiveness or savings of funds were identified, and work on the next phase of this study was outlined.

The feasibility study undertaken for the Maritime Administration to determine the use of automatic data processing techniques and equipment in support of their regulatory functions, including complex subsidy determination and marine engineering calculations, was terminated. The routine paperwork associated with the consideration of subsidies for the construction and operation of ships was analyzed, and it was concluded that mathematical calculations relating to the characteristics of ship hulls and propulsion equipment could be successfully transferred to a large-scale computer for routine operation.

Preliminary investigation of the objectives, functions, and operational units of the Office of Technical Services, U.S. Department of Commerce, was initiated to determine the feasibility of applying automatic data processing techniques to its activities and operation. OTS collects scientific literature and reports of Government-sponsored research, reproduces them, and sells them at the cost of printing and handling to scientific and industrial laboratories, private individuals, and business enterprises. In addition, OTS prepares catalogs and indexes, and conducts searches (for a fee) of technical documents originating in Government agencies and in the offices of their contractors. A general survey of the operations of each of the organizational units of OTS was begun as the first step in a detailed analysis of the functions of this agency and the demands made upon it.

Research Information Center. The collection and organization of literature and bibliographic references covering a wide range of interests in information storage, selection, and retrieval continued for the Research Information Center and Advisory Service on Information Processing, which is under joint sponsorship of the National Science Foundation and NBS. During the past year the collections of the pertinent literature, references, and other related material have more than doubled. Abstracts and/or complete texts are now available for over 5,000 literature items in the several fields of interest.

Work continued on a systematic glossary of terms, and specialized lists of workers active in the fields of character recognition and the theory of automata were selected from the files. In addition, specialized bibliographies were prepared and checked in connection with the preparation of several state-of-the-art reviews pertinent to the subject areas of information storage and retrieval systems and of mechanized translation. Two state-of-the-art studies—a survey of the present status of automatic character recognition and a guide to the literature of automata theory with special reference to potential applications in mechanized information selection and retrieval systems—were prepared for publication. The Center continues to give bibliographic and other services to cooperating workers in the field, government agencies, and interested correspondents.

Developments in Automatic Mail Sorting. The Bureau continued its assistance to the Post Office Department Office of Research and Engineering in applying automatic equipment and data handling techniques to the improvement of mail-sorting operations. A program was developed for testing and demonstrating prototype letter sorting equipment, and for emphasizing the experimental use of the installation to obtain human factors data and basic statistical data now lacking. In preparation for this program, manual sorting schemes or procedures were rewritten and further adapted for use with the code-sort equipment. These rewritten schemes were designed to utilize the flexibility of the code-sort equipment and to serve as a model for future sorting studies or new schemes. In addition, the revised sorting schemes were translated into a punched card format, and the code-sorting schemes are continually updated to reflect changes in the manual schemes resulting from changes in transportation schedules, adjustments to carrier routes, etc. A computer program was developed to assist in the analysis of possible future coding procedures, and an attempt was made to develop a computer program that selects "optimal" paths for routine mail. This is a variation of the well-known "shortest route problem" and is expected to yield procedures for evaluating new plans such as the "National Integrated Postal Service Plan." The operations of two new Post Offices that were designed to utilize the present state of the postal mechanization art were evaluated. The network studies of the sorting and transportation problem in its entirety were begun.

Mechanization of Patent Searching. Major emphasis in the cooperative program with the Patent Office for implementing the mechaniza-

tion of composition-of-matter patent search operations was devoted to planning, developing, and debugging large-scale data preparation and data checking routines. These routines are required in the preparation of error-free library files of disclosure information for use in trial runs using diverse types of realistic questions. The pactical applicability of chemical search strategies such as those incorporated in HAYSTAQ can then be determined. It is hoped that these experiments will result in meaningful statistics as to the most frequently recurring errors and the variation in incidence of error among individuals. Preliminary research on methods of file organization have also been in progress, the objective being the development of powerful screening methods for increasing search efficiency.

Simulation of Traffic Flow. At the request of the Bureau of Public Roads, which is concerned with the design of more efficient highway signal systems, a program for simulating municipal traffic flow by means of high-speed automatic data processing and display equipment was completed. The program prescribes the rules for movement of randomly generated cars along the several blocks of 13th Street NW, Washington, D.C. between Euclid and Monroe Streets. A scanning program spots car positions and writes the coordinates on a magnetic tape. A computer using this information projects the car positions onto an oscilloscope and actuates a camera to take pictures of the successive position displays. Detailed tables that catalog all vehicles as they enter the test course, clock and count the vehicles as they pass a key intermediate point, and finally check out the vehicles at the end of the course noting their running time, are produced as a byproduct for further analysis. Other information furnished includes the type of vehicle, speed, and lane use. These tables furnish an abundance of quantitative data for measuring and evaluating the performance of the model.

2.3.3. INSTRUMENTATION

Measurement precision depends on two factors: The natural limitations of the measurement process, and the realizable performance of measuring instruments. Under a broad instrumentation program, the Bureau investigates both of these factors to improve its measurement capability in research and calibration activities. The fundamental properties and limitations of instruments, their components and materials, as well as measuring, recording, and signal-processing methods, are studied. The program also includes study of basic phenomena that may be usefully applied to instrumentation.

Modern instrumentation frequently uses electronic techniques, even when the initial measurement problem is not fundamentally electrical. The electronic program includes investigation of the materials used in vacuum and semiconductor electron devices; study of the characteristics and capabilities of electron devices themselves; the development of improved electronic instruments to meet the needs of the Bureau's research program; and a variety of projects undertaken for other Federal agencies.

Right: The anchored, unmanned, automatic weather station, "Nomad," developed for the Navy, was the first automatic weather station to detect formation of a hurricane. Above: NBS engineers also helped the Navy to develop and set up a chain of automatic weather stations in the Antarctic (page 120).

Mechanical instrument activities include development of standard hygrometers and humidity generators, calibration methods for pressure and displacement transducers, and study and development of instruments needed specifically by other Federal agencies.

To avoid duplication of scientific research effort, it is necessary to keep abreast of the instrumentation art. The Bureau therefore maintains an extensive reference file of literature on instruments and measurement methods. The file itself is designed so that its data can be retrieved partly by mechanical means.

Meteorological Instrumentation. The Bureau developed an anchored automatic weather station, and during the year weather information was telemetered from the station after it had been placed in a remote location on the ocean surface. The station was called NOMAD (Navy Oceanographic Meteorological Automatic Device). It was the first such station to be anchored successfully for a substantial period in more than 11,000 feet of water. It also was the first anchored automatic station to detect formation of a hurricane and alert weather observers on land. A special storm-sensing device contributed to this achievement. The station was developed as part of the ocean test and evaluation program, begun in 1957 for the Bureau of Naval Weapons, with NBS responsible for technical direction.

Antarctica Assistance. At the request of the Bureau of Naval Weapons and Navy Task Force 43, NBS engineers participated in Operation Deepfreeze 60 and Operation Deepfreeze 61. During the former a network of automatic weather stations was established on the Ross Ice Shelf, and along the coasts of Ross Sea and Bellinghausen Sea. The stations were developed by the Naval Research Laboratory, based on a World War II development at NBS.

During Operation DF 61 a more extensive network of stations was established on the Ross Ice Shelf and the Polar Plateau. Several prototype weather stations were used operationally for the first time. The data collected and transmitted automatically by these stations aided Navy meteorologists materially in forecasting weather for flights to, from, and within the Anarctic continent.

Hygrometry. The Bureau's basic reference for humidity measurement is a gravimetric hygrometer that determines the moisture content of gases on an absolute basis. All known sources of error for this instrument were analyzed and evaluated. As a result, it is estimated that the absolute humidity of a gas sample now can be measured with a standard deviation of 4 parts in 10^4.

Upper-atmosphere ballon flights were made from the Bureau with the NBS fast-responding electric hygrometer element, used with an improved a-c radiosonde circuit, to study performance of the hygrometer under field conditions. This work was partly supported by the Bureau of Naval Weapons. The experiments, which are still in progress, indicate that large humidity gradients, discrete humidity changes, and humidity microfluctuations can be observed. The element also was used on the Office of Naval Research high-altitude, manned balloon flight (Strato-Lab High No. 5) for measuring atmospheric relative humidity throughout the flight.

FOSDIC. An advanced type of Film Optical Sensing Device for Input to Computer (FOSDIC) is being developed for the Weather Bureau, where it will read and collate records of weather data prior to electronic data processing. The new FOSDIC will examine microfilmed punch cards being prepared by the Weather Bureau in its existing FOSDIC program. Features of the new machine include programed capability for detecting illogically punched or damaged data cards and ability to monitor its own errors and malfunctions. Alternative punch-card or magnetic-tape outputs are provided to ensure compatibility with both present and proposed data systems.

Telemetering Pickups. The Bureau investigates the characteristics of telemetering transducers, and methods for their measurement, as part of a program sponsored jointly by the Bureau of Naval Weapons, the Army Ordnance Corps, and the Air Force. During the year, a facility was activated for wave analysis of transducer responses excited by a shock tube. The resonant frequencies of pressure transducers can be ascertained with this equipment, and the resulting information determines the upper frequency limitation on faithful reproduction of pressure transients. The useful frequency range of the analyzer is 1 to 100 kcs.

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During the year, a pneumatic stepfunction pressure calibrator, which generates known pressures in the range from 2 to 100 psi, was completed. The generated stepfunction attains an amplitude constant to within ± 2 percent within 15 milliseconds. The final pressure is known to within ± 0.1 psi.

Electronic Fault Location. A program, sponsored by the Navy Bureau of Ships, is underway to develop techniques for measuring rapidly the performance of electronic circuits in working equipment. Such equipment often is composed of electric subassemblies, or modules; and a method is sought to enable the semiskilled maintenance man to quickly locate and replace any defective module. Simple procedures using bridge methods are being worked out for testing amplifiers, waveform generators, and timing circuits. A catalog of these techniques will be prepared.

Electron Emission of Thermionic Cathodes. Carbonates of barium, strontium, and calcium were deposited on nickel cathode surfaces by an improved electroprecipitation process. This is an alternative method for applying the emissive material to the cathode of electron tubes. The method is a simple plating procedure using a filtered solution of the bicarbonate in water. Its principal advantage is ultracleanliness, yielding coatings of pure carbonates uncontaminated by the ball-milling, organic vehicles, and soluble salts involved in conventional techniques. The process can be adapted for various cathode shapes—cylindrical, plane, conical, etc.—and the small laboratory now can maintain control of coating density and texture as well as purity.

Because of hydrogen evolution at the cathode, mechanical motion of the electrolyte over the cathode surfaces is essential. An electrolyte tempera-

Microcite, a close-coupled searching machine developed for use with the NBS punched-card (peek-a-boo) instrumentation index. The operator can locate references, view abstracts on the screen at the top, and make copies of the selected abstract automatically (page 123).

ture of approximately 10 °C is desirable. The throwing power is poor, so that any simple means is effective for surface masking.

Vapor Pressure of Alloys. A vacuum microbalance with a sensitivity better than one microgram was used to determine vapor pressure of the minor constituent in nickel-base alloys. Alloys of this type are important in manufacture of electron tubes. Samples containing approximately 0.1 percent of magnesium, aluminum, and titanium were measured successfully. For satisfactory measurement, the impurity diffusion rate must exceed its loss at the alloy surface, and a vacuum pressure less than 10^{-9} torr is needed to prevent combination of the impurity with gas at the surface.

Instrumentation Reference Service. A searching machine was developed for use with the punched-card (microcite) instrumentation index. The machine enables an operator to identify quickly all information in the index on a particular instrumental or measurement subject. Meanwhile, simple methods were developed for replicating the punched cards used in the Bureau's reference index. The same techniques are expected to be useful in performing information searches based on logical sum and logical difference.

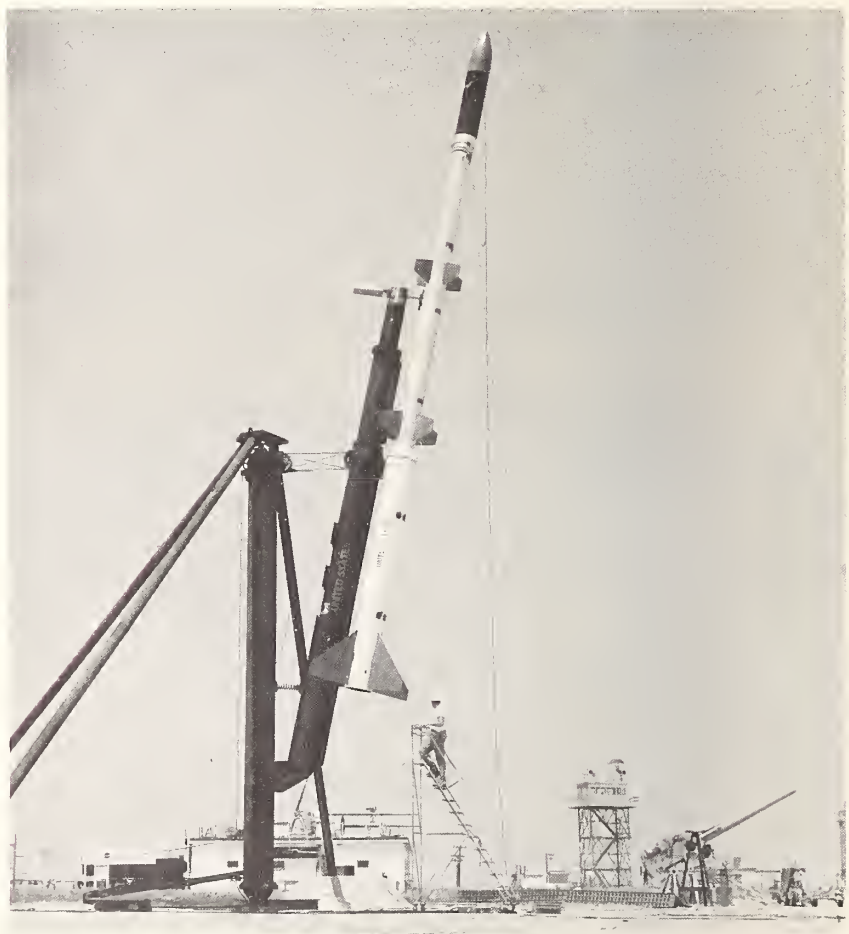
Technical Communication. Communication among scientists and organizations is an effective means for avoiding needless duplication of effort. A study of the state of such communication, relative to the electronic research program of the Federal Government, was made for the Senate Subcommittee on Government Reorganization and Internal Organizations of the Senate Committee on Government Operations.

2.3.4. RADIO PROPAGATION

The Central Radio Propagation Laboratory, located at Boulder, Colo., has the primary responsibility within 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, through the atmosphere, and in outer space. To carry out its responsibility, this Laboratory conducts research on the nature of radio waves and the media through which they are transmitted, the interaction of the waves with media, and the nature of the radio noise and interference effects. A network of field stations is operated from the Arctic to the tropics, and data are exchanged with other laboratories throughout the world. A newly established mathematics group is responsible for mathematics and computational procedures at the Boulder Laboratories. To assist this program a large transistorized computer was acquired, and is now being used in the solution of such problems as propagation of VLF–LF radio waves, the true height of the inonosphere, radio ray tracing, ionospheric mapping, and cryogenic properties of materials. The work of the Laboratory is divided into four areas: Ionosphere research and propagation, radio propagation engineering, radio communications and systems, and upper atmosphere and space physics.

IONOSPHERE RESEARCH AND PROPAGATION

The Bureau conducts and coordinates basic research on the propagation of radio waves as affected by the ionosphere and on the special factors which can give rise to large departures from the normal behavior; conducts basic research on the nature of the media through which these radio waves are transmitted and the interaction of radio waves with the media; prepares predictions of radio wave propagation and warnings of disturbances; acts as a central repository for data, reports, and information in the field of ionospheric radio wave propagation; and provides consultation services on the characteristics of the ionosphere and on radio wave propagation to other government agencies and industry.



Javelin rocket which carried an ionosonde to an altitude of 1,000 kilometers. For thirteen minutes, the ionosonde made topside soundings of the ionosphere. The experiment was made to test the sounding system for the fixed-frequency satellite topside sounder to be orbited in 1962 (page 127).

VLF Phase Stability Studies. Propagation characteristics of phase stabilized transmission in the very low frequency (VLF) band of the radio spectrum are studied to provide data on the state of the lower ionosphere. A record of the phase and amplitude of a VLF transmission discloses the normal variation in the phase resulting from changes in the effective height of reflection of the ionosphere from day to night. Abnormal variations in the phase of a VLF signal are observed to accompany both magnetic storms and solar flares (Sudden Phase Anomalies). An unusually large Sudden Phase Anomaly (SPA), produced by a solar cosmic ray flare, was observed at 1030 UT, 4 May 1960 on the record of the 16 kc/s GBR transmission from Rugby, England, to Boulder, Colo. The high energy cosmic ray particles produced by this solar flare ionized a region well below the normal *D*-region of the ionosphere, thus producing the large SPA. (Only 10 such solar flare cosmic ray events have been observed in the period from February 1942 to December 1960.)

In addition, analysis of the 16 kc/s data has revealed variations in phase coincident with meteor shower activity. The use of the phase-coherent detection technique at VLF is apparently a sensitive indicator of the worldwide ionizing effects of meteors which are not as easily seen in smaller volume samples, such as those obtained by VHF forward scatter, radar, and optical observations.

Magnetic Field Micropulsations and Electron Bremsstrahlung. Enhanced magnetic micropulsation activity in the auroral zone near College, Alaska, has been observed simultaneously with increases in electron bremsstrahlung intensity. Measurements of the magnetic field fluctuations were made with a 2-m-diam loop antenna of 21,586 turns with its axis in the magnetic North-South direction. The system had a flat response to magnetic flux density in the frequency range of 0.4 to 0.04 c/s. Bremsstrahlung from bombarding electrons having energies greater than 50 kev were observed with balloon-borne Geiger counters. X-ray bursts, representing high energy electron influx, were found to be coincident with the magnetic field micropulsation amplitudes. Balloon measurements of electron bremsstrahlung using rapid time response scintillation counters give some indication of the existence of bunching in the incoming electron density. Further observations should show whether such fluctuations are also simultaneous with the magnetic field pulsations.

Ray Tracing Through The Real Ionosphere. Ionospheric data collected during the IGY show that large regions of high electron density exist in the vicinity of the magnetic dip equator. Under such conditions the assumption of a spherically stratified ionosphere is invalid and it becomes necessary to plot the radio wave ray paths in detail so as to ascertain the modes of propagation.

Cross sections, along the 75° west meridian, have been made for noon and evening conditions in March 1958. Neglecting the earth's magnetic field, rays have been constructed from a point located at 20° North latitude for several frequencies and angles of elevation.

Mountain-top transmitting location for studies of fading characteristics in wide-band transmission systems. Receivers are located at a distance of 70 miles on the plains within the line-of-sight. Problems of space telecommunications have led to a need for more data on long line-of-sight transmission paths (page 128).

Of particular interest is the presence of supermodes. These involve ray paths that undergo two successive reflections from regions of high electron concentration without the usual ground reflection in between. In this way signals can propagate at frequencies considerably higher than the classical maximum usable frequency.

Doppler Fading Studies. Over the past year a sensitive technique has been developed for the recording of the frequency variation of ionospherically propagated radio waves. These frequency variations are of the order of a few cycles per second and for purposes of analysis they are recorded on magnetic tape traveling at a speed of $\frac{1}{50}$ ips. By playing the tape back at a speed of 30 ips the frequency variations appear as an audio tone which can be analyzed by conventional techniques.

The 20 Mc/s transmission of WWV has been recorded at Boulder for a number of months in the winters of 1959–1960 and 1960–1961. Within a minute of the optical onset of a large solar flare of November 12, 1960, the frequency started to increase. This increase can be interpreted as a downward motion of the reflecting level. Later the ionosphere stopped moving and the frequency returned to normal. This technique can also be used to identify magnetic storm effects and traveling disturbances in the *F* region. During a severe magnetic storm it has been observed that the *F* layer loses its specular reflection character and degenerates into a turbulent medium.

First Rocket-Borne Soundings of the Topside of the Ionosphere. Shortly after 1800 EST on June 24, 1961, a two-frequency ionosonde was carried to an altitude of over 1000 km off Wallops Island, Va., by means of a four-stage rocket (Javelin). Successful radio pulse reflections from the topside of the ionosphere were obtained for about 13 of the 15 minutes that the payload was above the height of the *F* region maximum electron density. The experimental technique involved is essentially the same as that used by the network of bottomside sounders except that the rocket-borne sounder was completely transistorized and operated at a lower power. Unexpected effects were observed as the sounder passed through levels in the ionosphere where the plasma frequency was equal to the sounding frequency. Also, some evidence for the presence of ionization irregularities at altitudes of 700–900 km was obtained. A preliminary analysis of the rocket results suggests a neutral atmosphere scale-height of about 70 km between the altitudes of 400 and 600 km, implying a temperature of about 1,200 °K (assuming an oxygen atmosphere).

The purpose of the rocket experiment was to test the sounding system that is to be used in a fixed-frequency satellite topside sounder scheduled to be placed in orbit in 1962. NBS responsibilities in this program include overall planning, design and performance of the experiment, and analysis of the resulting data. Airborne Instruments Laboratory, a division of Cutler-Hammer Company, is designing and building the rocket and satellite payloads and the ground data handling equipment. Technical management and sponsorship is provided by the National Aeronautics and Space Administration (Goddard Space Flight Center).

Studies of the Interplanetary Medium. A study of the relation of solar emission of medium-energy particles to other types of solar activity has revealed new facts about the interplanetary medium. These particles, first suspected in the large solar event of February 1956, have been detected in the earth's atmosphere and their effects studied by means of VHF forward-scatter signals. These data, and others measuring the ionospheric effects of the solar particles, show that around the time of maximum solar activity the solar cosmic ray particles take much longer to reach the earth from the sun than they do near minimum activity. Comparison with characteristics of solar particles of higher and lower energies show that these medium-energy particles must move in the interplanetary magnetic field not as single particles, but as a group. Consideration of directly-observed energy spectra of the various solar particles show that this group behavior is to be expected if the interplanetary field is regular but weak near solar minimum activity, and contains regions where the magnetic field intensity is 10^{-4} or 10^{-5} gauss near the maximum of the solar activity cycle. Linear dimensions, field strength, and frequency of occurrence of these regions of enhanced magnetic field, estimated from the behavior of the solar particles, are found to be consistent with the hypothesis that the clouds are formed through the action of low-energy solar particles. The effect of these outward-moving magnetic clouds on the velocity distribution of cosmic rays accounts for the main features of solar modulation of cosmic rays.

Radio Reflections from Artificial Electron Clouds. In a cooperative program with the Air Force Cambridge Research Laboratory, the Bureau has been involved in the operation of strategically located ionosondes during rocket experiments aimed at the creation of electron clouds. In these experiments relatively small amounts of various substances (such as sodium) are injected into the atmosphere at ionospheric heights. In one class of experiments, clouds of free electrons result through the ionization of the ejected material by sunlight. By permitting a measurement of the radio distance to ionized clouds over a wide range of radio frequencies, the ionosonde is a valuable tool for the study of cloud position, drift, and growth. Studies of the drifts of these clouds allow determination of wind velocities and the height gradients. For example, a value of about -7m/s/km was deduced for the East-West height gradient of the drift speed at 100 to 120 km during July–August 1960 over northern Florida.

RADIO PROPAGATION ENGINEERING

More efficient use of the radiofrequency spectrum is the aim of the Bureau's program in radio propagation engineering. This objective requires a basic understanding of radio wave propagation, noise, and interference. To this end theoretical and semi-empirical prediction methods are developed and compared with statistical samples of data on radio wave propagation and radio noise. During the past few years it has been found desirable to increase emphasis on the direct measurement of the characteristics of the atmosphere which affect the propagation. Further emphasis is also being given to studies of propagation and noise at the two extremes of the useful spectrum: above 5,000 Mc/s and below 30 kc/s. In this way it is hoped that a better understanding of these portions of the spectrum will lead to their more extensive and efficient use.

Tropospheric Transmission Loss Predictions. New methods were published in the past year for predicting the transmission loss expected on a point-to-point tropospheric radio circuit. These thus provide an accurate basis for designing such radio systems. The accuracy of these prediction methods is such that costly path loss measurements prior to the installation of such a communications system are no longer necessary: These measurements can often be misleading unless they are made over a sufficiently long period of time, which in some cases may be several years.

Wideband Data Transmission. Current use of radiofrequencies, with the transmission of large amounts of information, often involves very wideband systems. The advent of space telecommunications and high-altitude space vehicles has made it necessary to consider very long line-of-sight paths involving transmission through the troposphere. A measurement program has been initiated to investigate the maximum effective bandwidth that the troposphere can support without serious distortion due to multipath effects both within and beyond the line-of-sight. The within-line-of-sight observations have been made from a mountain site in Colorado

towards the plains, using two microwave signals separated by a difference in frequency corresponding to very wide communication bandwidths. The beyond line-of-sight measurements are being made between Boulder, Colo., and Altus, Okla., using large parabolic antennas ranging in size from 14 to 60 ft in diameter at the receiving and transmitting terminals. The information obtained will help to determine the ultimate volume of information that can be transmitted over long tropospheric paths and assist in the design of systems employing this type of propagation.

Mutual Interference Between Surface and Satellite Communication Systems. Artificial earth satellites have opened up new horizons in long distance communication possibilities. Optimum frequencies for satellite communication purposes lie generally in the 1,000 to 10,000 Mc/s portion of the radiofrequency spectrum. Since this portion of the spectrum is presently in use by many communication services, satellite communication

Receiving antennas used in studies of obstacle-gain propagation over Pikes Peak. Under certain conditions, signals propagated across mountain ridges are found to be far stronger than if the obstacle were not there (page 130).

systems will be expected to share frequencies with these existing services. Predictions have been made of the conditions under which these frequencies can be shared by conventional point-to-point microwave relays and satellite systems. A study sponsored by the Joint Technical Advisory Committee of the Institute of Radio Engineers predicts that frequency assignments may be shared if adequate geographical separation of terminals is provided. Theoretical studies and an experimental program using the NBS 60-foot parabolic antennas were conducted to determine the minimum separation distance and the minimum antenna elevation angles for the space communication system, such that the interfering signal power appearing at the receiver input terminals was below the interfering level. In order to make reliable estimates of these interfering conditions, these measurements will necessarily be conducted over an extended period.

Technical Factors Influencing Allocations. The advent of space telecommunications, together with the increasing use being made of the crowded radio spectrum, requires the application of technically sound procedures in radio frequency allocations to assure maximum efficiency of usage and adequate provision for all radio services. The Central Radio Propagation Laboratory, in cooperation with the Interdepartment Radio Advisory Committee and the Federal Communications Commission, has undertaken a general study of propagation factors important in radio frequency allocation, giving consideration to all types of radio service presently in use or of future concern.

Signal Characteristics of Mountain Obstacle Paths. Under certain conditions signals propagated across mountain ridges are found to be far stronger than if the mountain were not there. In order to take optimum advantage of this effect it is necessary to be able to estimate the variation in transmission loss over these paths and to understand the conditions under which space diversity may be used to overcome fading. A long-term series of measurements was completed in eastern Colorado using Pike's Peak as a knife-edge type obstacle. Sample recordings were made at two frequencies (100 and 750 Mc/s) over a period of nine months. Empirically derived functions based on line-of-sight fading phenomena specially adapted to this type of propagation give results which closely approximate the measured fading characteristics.

Refraction Effects in Microwave Tracking Systems. Modern precision missile radio guidance systems using microwaves have their ultimate accuracy limited by the refractive index irregularities in the troposphere. A program is being conducted to measure the effects of atmospheric inhomogeneities and turbulence on such systems. Using specially developed techniques on the unique terrain of the Boulder area, an experimental tracking system was constructed to simulate the basic functions of the Mistram system being built for the Air Force. This system is being used to record the variations in apparent positions which result from atmospheric variations. Simultaneous recordings are made of various atmospheric quantities such as

Airborne refractometer equipment used in studying the effects of atmospheric inhomogeneities and turbulence on missile radioguidance systems using microwaves (page 130).

Radio propagation paths under study by the Bureau to provide information on factors affecting the design and use of radio systems. Ionospheric, groundwave, and line-of-sight paths are investigated to define the limitations, disturbances, and capacity of the transmission medium as a channel (page 128).

refractive index at each of the antennas in the system, and at a number of height levels on a tower near the terminals of the system. In addition, microwave refractometer measurements are made by an aircraft flying approximately along the propagation paths. These data are being examined for correlation with the apparent position variations of a fixed target simulating a missile to investigate the feasibility of using them for correcting the radio system data. Preliminary work has shown that some of the long-term (several hours or more) atmospheric effects can be reduced significantly by proper atmospheric measurements. However, no methods have been found as yet to make significant or reliable correction for the short-term effects (hourly or less).

Radio Meteorological Sensors. The results of an investigation concerned with the problem of time-lag constants in the humidity and temperature sensors of standard radiosonde instruments currently in use by civilian and military weather organizations shows clearly that corrections for the time lag in the sensors of both parameters are necessary for correct interpretation of the observed readings. Radiosonde observations have been universally used for determining the radio refractive index properties of the atmosphere with altitude; such observations are required not only for predicting the normal refraction of radio waves around the curved surface of the spherical earth, but are also used for predicting the strength of signals resulting from atmospheric turbulence and tropospheric waveguide propagation commonly known as ducting. It is especially important to take into account the time lag of these radio meteorological sensors in studying the climatological occurrence of radio ducts. By ignoring sensor time lag one tends to underestimate ducting incidence; by correcting only for humidity sensor lag, ducted incidence is overestimated.

Atmospheric Refractivity Models. The variation of the refractivity of the atmosphere with height above the surface of the earth is important in the prediction of tropospheric radio field strengths. A study of refractivity with height made by radiosonde observations throughout the world indicates that a satisfactory model of the atmosphere can be represented by the sum of two exponential quantities, one dealing with the dry properties of the atmosphere, and the other dealing with the humidity properties of the atmosphere. The dry and wet exponential terms are sensitive indicators of climatic differences, and in the course of the study maps of each were prepared for the United States for both summer and winter. The bi-exponential model yields more accurate estimates of refractivity structure in the troposphere than the earlier single exponential model, and consequently gives more reliable estimates of refraction for initial elevation angles in excess of 3°. Only negligible improvement for the near zero angles of departure commonly used in tropospheric propagation are obtained.

Automatic Amplitude Distribution Analyzer. An analysis system for determining the principal statistical parameters of time varying radio propagation data was completed. These parameters are cumulative amplitude distribution, fade rate versus data level, fade or enhancement duration

distribution at specific data levels, and the distribution of percent of time preset fade or enhancement durations are exceeded. The system is designed to analyze data recorded on magnetic tape, making it possible to analyze most field data at a rate 100 times the speed at which it was recorded. The input data is in the form of variable voltage, representing the fading characteristics of the strength of the measured radio signal. The results are automatically recorded on a digital printer at the end of each analysis period.

Engineering Standards for Tropospheric Communication. A revised and updated 360 page handbook of engineering standards for tropospheric telecommunications was prepared, partly in response to demand in excess of the 1960 edition and partly at the request of the Air Force for a shorter version of the material. Methods for calculating system performance and equipment requirements for line-of-sight, knife-edge diffraction, smooth and rough earth diffraction, and forward scatter are given with several new concepts and a general updating over the original handbook.

Prediction of Radio Noise from Thunderstorm Counts. Since atmospheric radio noise originates in thunderstorms, an attempt has been made to predict the radio noise, at any location, from world-wide thunderstorm counts.

From available records of thunderstorms, the probability of a thunderstorm occurring during any hour in each of the four seasons has been computed for any geographic location. Using the computed number of thunderstorms over the globe for any time, and season and propagation characteristics for the various frequencies and paths, the noise power received at any location may be calculated for the same time and season, providing the average power from an average thunderstorm is known. By assuming a value for this average power, comparisons of measured power and calculated power at each of the seventeen stations in the CRPL radio-noise-recording network can be made. The average power from a thunderstorm found from this comparison can then be used to calculate the noise power at any other location.

To date, due to the volume of computation necessary, only one check (at 50 kc/s) has been computed for one continental location. In this one check, the computed diurnal and seasonal variation of noise are in good agreement with the recorded noise.

RADIO SYSTEMS

The aim of the radio systems program is to provide technical information relating to propagation factors affecting the 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, ground wave and line-of-sight paths to define the limitations, disturbances, and capacity of the transmission medium as a channel. The information obtained is directed toward guidance of engineering practices, allocation and use of radio frequencies, and evaluation

Array of 25 Yagi antennas used to pinpoint the direction of radio signals received from "forward scatter" transmission (page 136).

of system capabilities and limitations. Standards and methods of measurement are developed for radio systems to fulfill 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.

Low and Very Low Frequency Systems (30–300 kc/s). Theoretical computations of the propagation of ELF and ULF electromagnetic waves have been carried out to provide a solution for the propagation of spherical waves in and about a spherical earth of finite conductivity. A flexible theoretical computing model for the lower ionosphere was developed for VLF–LF–MF and HF wave propagation. The model is a multi-slab electron-ion plasma with superposed magnetic induction of arbitrary direction. Computations have been made of the effects of various types of disturbances on waves propagated via the lower ionosphere. Graphs, curves, and charts are being prepared to assist in practical system studies in the ELF, VLF and LF region.

Analysis of transient propagation of LF radio waves has been conducted to assist in evaluating the accuracy of pulse navigation systems. Techniques for transforming from the frequency domain to the time domain for analysis of linear systems were further developed. A method was devised and tested for measuring effective ground conductivity and long paths by comparison of recorded complex spectra of atmospheric (lightning discharge) waveforms. The nature and occurrence of atmospherics, as well as modulation and receiving techniques, are studied to improve methods for elimination or reduction of noise effects in VLF/LF systems.

High-Frequency Systems. Experimental studies of high-frequency ionospheric radio propagation over Arctic paths were completed for the Air Force and the Navy. Results were obtained on the attenuation, or transmis-

sion loss, of radio signals as a function of frequency over paths subject to severe ionospheric disturbances. Galactic noise (VHF riometer) absorption measurements taken at vertical incidences near the path midpoint were compared with the oblique path transmission loss to determine useful relationships between galactic noise absorption and oblique high-frequency radio signal attenuation. The dependence of transmission loss on the geographical location of terminals and the angle of signal arrival was investigated for paths transiting the Arctic. The short term pulse-to-pulse and amplitude perturbations during ionospheric disturbances were investigated to determine modulation limitations for HF arctic circuits.

A study was completed showing the effect of the radiation angle upon high-frequency transmission loss for long-range transmission.

Previous experiments have suggested that certain high-frequency radio waves may be propagated by ducting along the magnetic field lines of the earth through the exosphere. The experimental program is being expanded by higher pulse powers and a continuous wave radar technique for more detailed study of propagation of backscatter echoes. Frequency shifting will be used to obtain the wavelength dependence of this propagation mode. The statistics of the occurrence of this mode of propagation will be examined, including the change in path transmission loss.

An electronic computer program for computing the path Maximum Usable Frequency and Optimum Traffic Frequency has been completed for the Navy. The program utilizes for ionospheric input data the numerical mapping technique developed by another NBS laboratory. With this program it is only necessary to know the path coordinates, month, and solar index to determine the usable frequencies as a function of time of day. The program, which can be readily changed to accommodate any particular system, is being extended to cover Lowest Useful Frequency computations.

A study is being conducted for the Navy to determine the applicability of electronic computers to real time computation of the optimum operating frequency for any HF circuit. All known factors influencing the performance of HF radio circuits are being examined to determine their predictability and usefulness for the computer techniques.

Comprehensive high-frequency propagation studies on behalf of the Advanced Research Projects Agency are being undertaken to measure phase and path-length changes, and group path time delays. This program is directed toward determining the short-term behavior of the natural ionosphere in relation to limitations of nuclear detection at long ranges. Both short and long term variations will be measured to determine sporadic and cyclic effects. A study was undertaken to determine instrumentation requirements for observations of the fine structure of the ionosphere by the observation of the amplitude, phase and polarization of both backscattered and forward propagated signals.

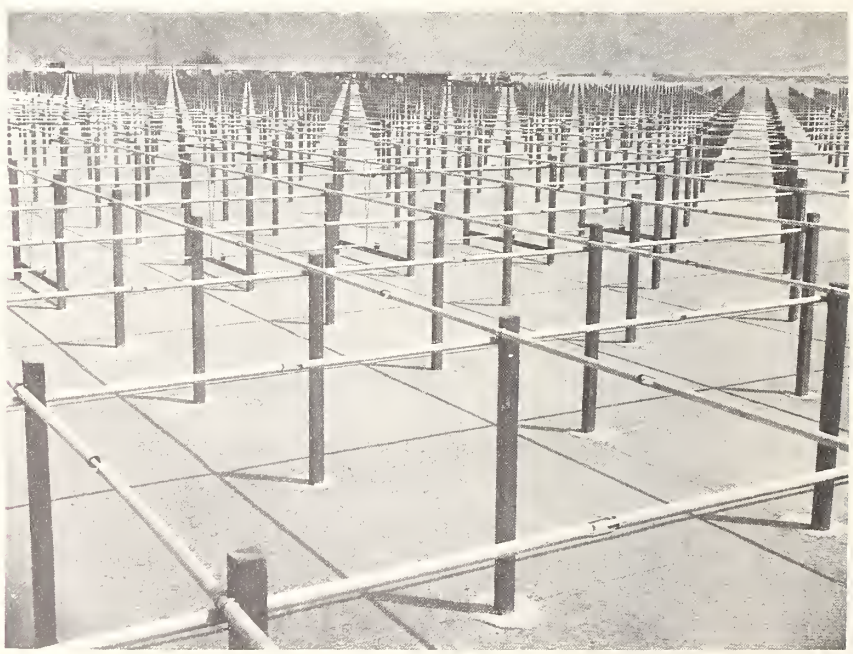
Planning has begun for a new high-power ionospheric radar research facility for HF and VHF studies, to be located at CRPL near Boulder Laboratories.

The U.S. Air Force has made available components of a Ballistic Missile Early Warning System radar transmitter which will serve as the power supply and nucleus of the 5-million-watt research radar.

Very High Frequency Systems. A long-term project on the study of signals scattered from the *D* region was continued. Signals were recorded at 30, 40, 50, 74, and 108 Mc/s through September, and at 30 and 50 Mc/s following completion of the frequency-dependence program at that time. It was determined that signals at the lower VHF frequencies suffered longer fade durations. Characteristic depths of fade are dependent upon prevailing transmission loss and are greater under weak signal conditions. The power spectrum of the received signal increases with carrier frequency and antenna beamwidth. Average signal-envelope fading is greatest near midnight and lowest near noon.

Antenna Research. An electronically scanned antenna capable of high scan rates was expanded to 25 elements, giving a 1½° beamwidth. Observations of path direction variation of ionospheric scattered signals were demonstrated. This technique of antenna steering is expected to be valuable in observing the direction of arrival of radio signals arriving from the great circle path.

The principles of the electronic scan—demonstrated by the successful operation of the seven-element array—were further developed. The array was increased in size to 25 Yagi elements so that the overall width is now approxi-



Part of a single antenna, consisting of 18,000 dipoles and covering 22 acres, built near Lima, Peru. The antenna will be used to probe the ionosphere, exosphere, interplanetary medium, and sun by means of radar (page 140).

mately 800 feet (33.6 wavelength). The width of the main beam was reduced to between 1.5 and 1.7 degrees, giving a rather fine-grain resolution between the components of signals arriving from different directions.

The equipment was operated successfully in order to collect data and to develop techniques for recording, interpreting and displaying the data. On June 16th an observation was recorded of signals arriving simultaneously from two directions via sporadic-*E* reflections. It is believed to have been the first such observation on record.

Studies and experimental measurements are being conducted to provide an improved antenna capable of receiving multiple steerable beams for any direction of transmission or reception. Concentric circular arrays of vertical monopoles using phasing and amplitude tapering are being studied. Measured results approaching theoretical expectations have been obtained on an array of one center element, an inner ring of ten elements, and an outer ring of 20 elements operated at 90 Mc/s. Construction of a 20 Mc/s model is underway.

A comprehensive study is being conducted on techniques and methods of measuring complex fields. Waves of arbitrary polarization and with multiple propagation paths and directions of arrival are being considered. The purpose is to develop a procedure for determining the response of any antenna (of known response pattern) to a complex field. Methods are being developed and tested for measuring amplitude, direction of arrival, polarization, and relative time phase of several multipath components of a complex field. Field-strength meters are being examined for their adequacy for both cw and pulse measurements.

Modulation Research. The chief obstacles to obtaining reliable signal transmission through the ionosphere are atmospheric noise, time-variant transmission loss, and multi-path propagation. One of the principal aims of the modulation research program is to characterize the time-variant, dispersive nature of ionospheric channels and the noise limitations at the receiver. In order to study the effect of channel distortions on signals it is also necessary to study the nature of the "communication source function" or the input modulation to the channel.

During the past year a survey of results obtained in many laboratories throughout the world on statistics of human speech as a modulating signal envelope has been made and supplemented by laboratory measurements. The effects of pre-emphasis of high audiofrequencies and clipping and filtering of speech signals has been studied. In channel characterization, significant advancements were made in the observations of pulse-to-pulse phase stability and pulse-amplitude fading over high-frequency auroral paths. Using pulses of 1 to 20 milliseconds duration, phase perturbations between successive pulses were analyzed over the path from Barrow, Alaska, to Boulder, Colo. Interpretation of the results was aided by concurrent sweep-frequency ionospheric soundings and oblique incidence measurements over the same path. It was found that the phase variations on this path mainly represented rapid movements of ionospheric irregularities rather than interference effects between separate modes of propagation.

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A new program has been initiated in information theory and coding for radio channels. New requirements for great communication capacity and reliability, with corresponding demands to reduce congestion in the radio spectrum, suggest a trend toward digital transmission in the design of communication systems. This trend is fostered by developments in digital computers and the theoretical tools of information theory and coding. To approach the accuracy and efficiency of transmission indicated by Shannon's Theorem, digital transmission is essential. In this program a preliminary study and report has been made of the applicability of error-correcting codes in radio circuits as compared with existing error-detection automatic-repetition systems such as the ARQ.

Further improvements were made in techniques for noise reduction and multiple frequency shift digital transmission in the VLF band for defense applications.

Navigation and Timing Systems. A year ago, feasibility was established for time synchronization of clocks separated by up to 1,500 miles, to an accuracy of one microsecond, using clocks associated with a low-frequency Loran C navigation system. The 100 kc/s ground wave pulse is used. Time synchronization obtained by this means is approximately 1,000 times more precise than that obtainable by using high-frequency radio techniques such as WWV radio signals, and probably 10 to 50 times better than obtainable with very-low-frequency transmissions. The study was carried out for the U.S. Air Force, and the synchronization was demonstrated on the Atlantic Missile Range for application to launching and tracking problems. Further studies have been carried out on possible extension of the distance range by use of sky-wave signals.

The work on the Loran C clock provided background for design and construction of instrumentation for an atomic time accumulator, for use with the NBS national primary standard of frequency. Times derived from astronomical sources are subject to errors of the order of 1 millisecond for any given observation. A clock operating from the best available frequency source is capable of measuring time intervals to better than 1 microsecond as related to that frequency source. This program will provide a means for the Bureau to maintain a time scale based on the period of an atomic transition. Several such times scales are being maintained internationally, and their comparison is of scientific importance, in view of international consideration of redefining the second in terms of an atomic transition. A means is also provided for the Bureau to check various time signals against an atomic source and to publish corrections of these time signals as they relate to the atomic time source.

The basic concept of this instrumentation is first, a number of pulse dividers to provide redundancy and allow for checks against each other; second, battery standby power to provide for uninterrupted service if primary power is interrupted; and third, a means for reading out or checking the dividers one against another. The objective of the entire instrumentation

Magnetic probes are used to study the hydromagnetic interaction between a shockwave and a magnetic field. Radio frequency radiations resulting from the interaction have been observed. This creation in the laboratory of electromagnetic radiation from plasma should lead to a better understanding of electromagnetic processes which occur in the upper atmosphere (page 140).

is to provide one second and one minute pulses derived from the 1 Mc/s standard frequency on a fail-safe basis. Instrumentation was essentially completed during the past year and component units will be integrated into the clock system early in the next year.

UPPER ATMOSPHERE AND SPACE PHYSICS

The research program in upper atmosphere and space physics recognizes the urgent need to increase the knowledge and understanding of the physical properties and processes in the media surrounding the earth and in interplanetary space. Such knowledge and understanding is essential to the expanding application of radio communication in the space age.

Preliminary Measurements of Electron Densities to 1,200 Kilometers. A new ionospheric research facility, based on the incoherent scatter of radio waves from free electrons, will provide the Bureau with a powerful and very sensitive research tool for important ground-based observations of the ionosphere, exosphere, interplanetary medium, and the sun. This major constructional effort is now underway at the new Jicamarca Radio Observatory near Lima, Peru, and important new advances are anticipated as soon as the 6 megawatt peak-power radar system is fully operational, probably during late FY 1962. Already one-half of the huge 18,000-dipole broadside antenna has been completed. Preliminary observations using part of the antenna system, and a relatively low-power transmitter, have given several electron density profiles to heights of 1,200 kilometers. These preliminary observations indicate that the decay of electron density with height above the maximum of the *F* region is usually exponential for several hundred kilometers. On several occasions a rather abrupt discontinuity has been observed in this exponential decay, in that, at great heights, the ionization is found to decay much more slowly than in the first several hundred kilometers above the peak of the *F* layer.

Radiation Produced from a Plasma. Plasmas produced by a high-velocity shockwave traveling at speeds in excess of Mach 100 in helium have been studied in the laboratory in the presence of a transverse magnetic field. Radiofrequency radiations resulting from the hydromagnetic interaction between the shockwave and the magnetic field have been observed. This creation in the laboratory of electromagnetic radiation from plasmas is a major step towards duplicating under controlled conditions electromagnetic processes which occur in the upper atmosphere. An additional important advance has been the development of a high-speed camera, capable of operating at a rate in excess of one hundred million frames per second and designed to study the luminous phenomena in the shockwaves.

Investigations in Particle Processes. Normal HF communications are notoriously unreliable at high latitudes due to disturbances resulting from bombardment of the upper atmosphere by energetic particles guided to these regions by the geomagnetic field. A major advance was made in studying this field when a 10 Mc/s riometer system was designed and constructed to measure cosmic noise absorption. This system records continuously the cosmic noise strength on both circular polarizations, and offers the advantages over earlier systems of a tenfold improvement in sensitivity, together with a greater dynamic range and an indication of the height at which the absorption occurs.

Cosmic Noise Study at USSR Mirny Base, Antarctica. In cooperation with USSR scientists, an important quantitative study of cosmic noise absorption as observed in the high southern latitudes was undertaken. This work will not only produce important data for the southern hemisphere, but it will also permit the determination of the relationships between absorption events occurring simultaneously in the two polar regions.

Satellite Radio Signals Used to Study Structure of Ionosphere. Communication with vehicles in space poses difficulties since signals from space as received on earth are perturbed by irregularities in the electron density of the ionosphere. By studying radio signals received from satellites it has been possible to measure the ionospheric electron content and irregularities above the region of maximum electron density. Previous studies of signals from radio stars and satellites provided evidence of ionospheric irregularities which are 100 to 500 km in horizontal extent, and which occur during daylight hours on about one-third of all days. The current studies include investigations of the size, shape and motion of these irregularities as observed at separate multiple observing stations.

Meteor Burst Propagation Observations Successful. A full scale field observational program was conducted to provide statistical information on the radio energy scattered by transient meteor ionization. This information is of great importance in studying the feasibility of meteor-burst communication between widely separated points, and in designing appropriate communication equipment. Measurements of propagation characteristics of transmissions at 30, 50, and 74 Mc/s were conducted over three paths of similar length. Two paths, crossing at right angles at the midpoint, were used in the U.S. to determine the dependence of meteor echoes on path orientation. The third path, in Alaska, was used to identify and measure meteor propagation characteristics peculiar to the auroral region. With successful completion of the field observations, the digitized data are now being analyzed to determine the pertinent propagation parameters.

Observatory Installed at Maui, Hawaii. The Bureau and the High Altitude Observatory of the University of Colorado have cooperated for some time in a study of the zodiacal light. Recently the collaboration has been extended to include the Hawaii Institute of Geophysics. An observatory has been established with National Aeronautical and Space Administration support on Mount Haleakala, Maui, Hawaii. The program includes, in addition to studies of the zodiacal light, systematic observations of the airglow.

Of particular interest is a strong correlation between the intensity of the atomic oxygen radiation (6300 A) and certain ionospheric parameters observed by the NBS ionosonde on the island of Maui. It has been found that the red (6300 A) line airglow intensities can be quite accurately predicted by a formula involving the parameters $foF2$ and $h'F$ on the ionograms. The nature of the correlation supports the hypothesis that the red line is due to excitation of atomic oxygen by a photochemical reaction involving either O_2^+ and electrons or NO^+ and electrons.

The photometric observations cover the entire sky and extend over a region of radius some 1,000 kilometers, in contrast with the ionosonde vertical soundings which are essentially overhead. The two techniques thus serve to complement each other and extend the scope of the investigation of the ionosphere.

A mobile satellite observing station, in conjunction with permanent facilities at Table Mesa, is being used to study ionospheric irregularities and their effect on the reception of satellite signals (page 141).

In mid-latitudes the relationship between the 6300–A emission and the ionosphere is less clear and it seems that the photochemical reaction is only one of several effective mechanisms. The results in the tropics may thus serve to give information clarifying ionospheric processes which occur in mid-latitudes.

Numerical Representation of the Ionosphere. Further work under this program has provided the first automatic computer methods for predicting long-term changes in useful frequencies for ionosphere radio communication systems. The methods used incorporate recent advances in applied mathematics and statistics in such a way as to respect as far as possible the empirical knowledge accumulated in ionespheric studies. The method developed provides important flexibility in solving problems of ionospheric radio propagation by treating separately the three basic areas involved: ionosphere mapping, correlation of ionosphere characteristics with various indices of solar activity, and application of the theory of radio wave propagation.

IGY WORLD DATA CENTER A

The Data Center continues to receive IGC and post-IGC data at a high rate. A special effort is underway to acquire and catalog all outstanding IGY data. During the year there was a notable increase in requests for data, most of the requests coming from scientific industry. Plans have been made to collect and exchange reprints and reports concerning Airglow and Ionosphere. This new service will aid scientists in the use of the materials available from the Data Center.

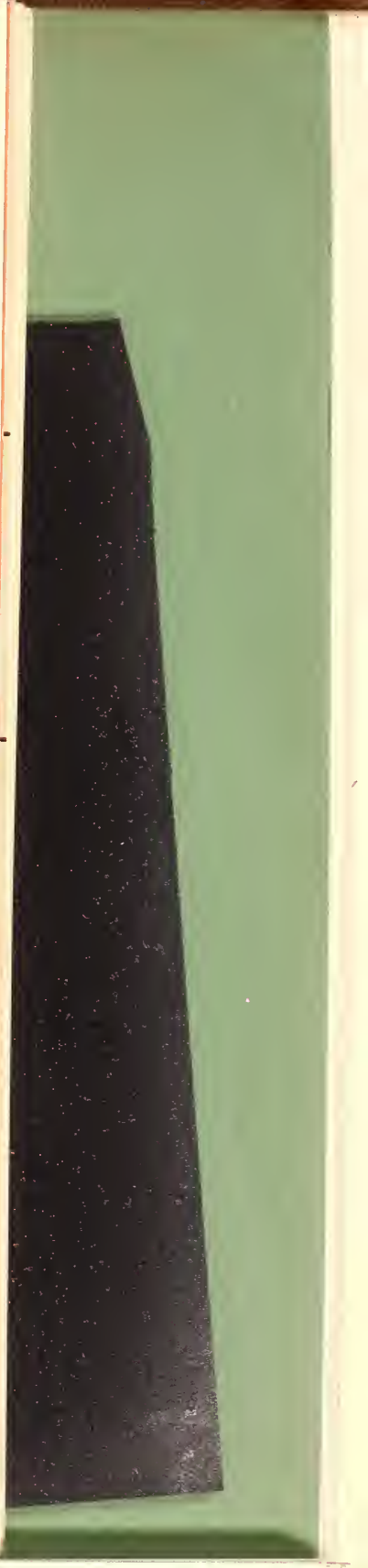
2.3.5. CRYOGENIC ENGINEERING

The Bureau's activities in cryogenic engineering, a rapidly growing specialized field, center at the Boulder Laboratories. The Bureau provides information needed for practical applications of materials, systems, and techniques at very low temperatures, and assists Government and industry with problems arising in this field.

Demand for assistance in projects involving cryogenics has increased greatly as a result of missile and space programs which rely on cryogenic liquids as propellants. The growth of cryogenic engineering has been accompanied by emphasis on purely scientific programs in which the use of extremely low temperatures can be an important aid. To cooperate in these activities, the laboratory conducts research on the physical properties of materials and properties of fluids, as well as on cryogenic processes and equipment. In addition, it maintains a national Cryogenic Data Center where information on cryogenic engineering is collected and organized for use by other Government agencies, industry, and the public.

Superconducting Electromagnets. High magnetic fields have important uses as deflectors of charged particles, as, for example, in the particle accelerators and detection devices of nuclear physics, in magnetohydrodynamic power converters, and for plasma containment in nuclear fusion reactors. Substantial reduction of the power dissipated as heat in electromagnets can be achieved if the magnet conductor is cooled to low temperatures so as to greatly reduce its electrical resistance. Until recently, the further step of utilizing a superconductor was not regarded as practical, because most superconductors are driven into the normal state by rather small magnetic fields. However, in the past year several alloys and compounds have been found to remain superconducting in the presence of high fields and while carrying large currents. One of these, niobium-clad Nb_3Sn, has been investigated by NBS. under Atomic Energy Commission sponsorship, in fields up to 190,000 gauss. The results indicate that solenoids can be made of this material that will produce fields of well over 100,000 gauss if operated at 1 to 4 °K. There is now intense activity in a number of laboratories on high-field superconductors.

Properties of para-Hydrogen. The specific impulse of a rocket propellant varies inversely with the square root of the masses of the ejected particles. Consequently the most advanced chemical and nuclear rocket schemes utilize hydrogen as a reactant and as a propellant fluid, respectively. Data concerning the thermodynamic and transport properties of hydrogen must now be known with higher accuracy and over wider ranges of temperature and pressure than have been hitherto necessary. With the support of the Air Force and, more recently, the National Aeronautics and Space Administration, the Bureau has completed precise measurements of the pressure-volume-temperature characteristics of liquid and gaseous para-hydrogen from 20 to 100 °K and at pressures up to 350 atmospheres. Measurements of the specific heat are in progress. Detailed thermodynamic charts and tables will be prepared from these data.

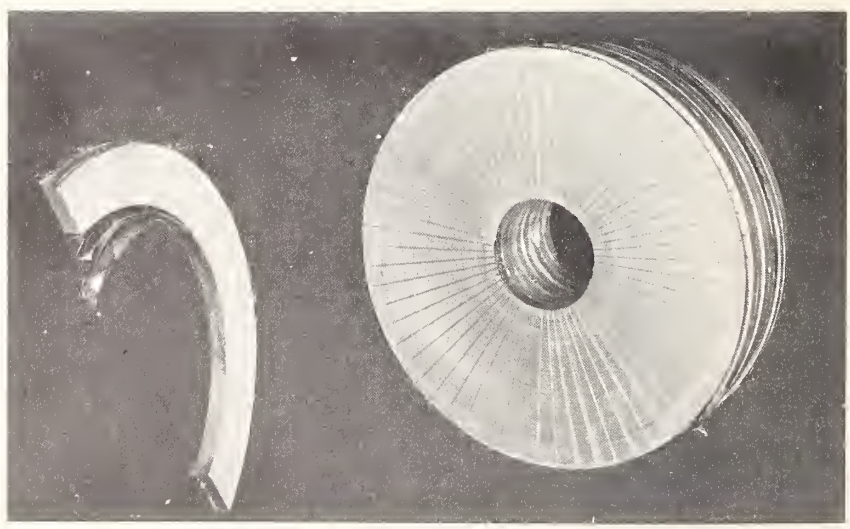


Cryogenic Materials Data Handbook. The performance of a liquid-propellant rocket depends critically on the reliability of valves and other control components. In turn, the design of such devices depends on the availability of accurate data on the physical properties of the materials used. The Bureau, under Air Force sponsorship, is compiling mechanical properties data, thermal expansions, and certain other physical properties data on about fifty metals, alloys, and plastics that are used in low-temperature equipment, and is making laboratory determinations where the data are lacking or are insufficiently accurate. A Handbook containing over 500 data sheets on these materials used in cryogenics is available from the Office of Technical Services, U.S. Department of Commerce.

Practical Thermometry. The thermoelectric characteristics of copper versus constantan, iron versus constantan, Chromel versus Alumel, gold-cobalt versus copper, gold-palladium versus platinum-iridium, and "normal" silver versus copper have been determined down to 4 °K. This completes the present program on the low-temperature characteristics of commonly used thermocouple materials.

Some of the first germanium resistance thermometers to become available commercially were calibrated at liquid hydrogen temperatures and were tested for stability under thermal cycling. Because of their small size, ruggedness, high resistance, and reproducibility, these thermometers should fill an important need for a practical thermometer for the region 1 to 40 °K.

A simple, empirical, interpolation method for platinum resistance thermometers was found which can provide the basis for a scheme of calibration



The amount of power needed to produce high intensity magnetic fields can be greatly reduced by cooling the magnet assembly with cryogenic liquids. Above is a liquid hydrogen cooled solenoid which was constructed using a stack of "flat doughnuts" made of turns of aluminum foil separated by paper (see section, left). The hole in the center of the solenoid is three inches in diameter; radial ducts in the "doughnuts" conduct the liquid hydrogen through the solenoid (page 146).

at low temperatures. By calibrating at the ice point, and the boiling points of hydrogen and oxygen, use of this method provides interpolation accurate within a few millidegrees down to 20 °K for precision capsule thermometers. (For other low-temperature thermometry, see page 56.)

Two-Phase Fluid Phenomena. Because the fluids in cryogenic systems are usually close to saturation, the simultaneous existence of both liquid and vapor phases (two-phase fluids) is common. A fundamental understanding of the behavior of these systems therefore requires basic knowledge of two-phase fluid phenomena.

Critical flows of two-phase fluids are being investigated theoretically and experimentally. An ability to predict these flows is necessary for the design of such cryogenic systems as those handling rocket propellants. Experimental work performed during the past year indicates that even when usual calculation procedures predict the contrary, limitations imposed upon two-phase flow systems by the existence of critical flows will occur.

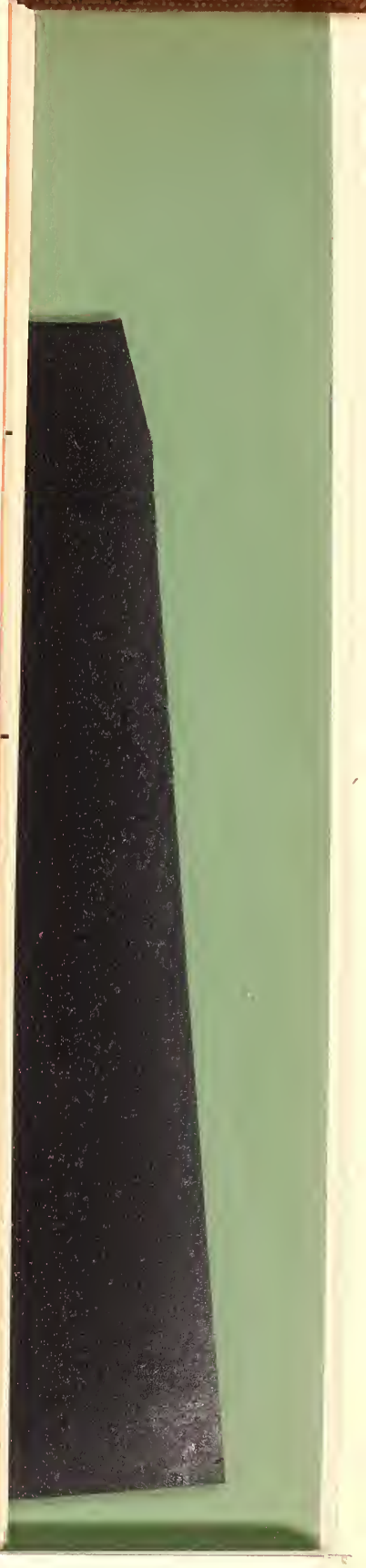
Basic investigations concerned with cavitation are also being undertaken. The emphasis in the present study is on metastability and nucleation characteristics of systems. Preliminary experimental results show, for example, that liquid nitrogen can be maintained in a greatly superheated condition for long time periods.

A study of the behavior of cryogenic systems during the transient period when the system is being cooled to operating conditions is underway. A very complete mathematical model is being solved numerically with the aid of a high-speed computer while dynamic instrumentation is being used to measure the pertinent variables (e.g., static pressures, momentum, flow rate, fluid and wall temperatures, geometry) in an experimental program.

The bulk density and density distribution of boiling fluids, and the bubble dynamics therein, are being studied. The present emphasis of this work is toward liquid oxygen, for application to space vehicles. The problem of cooling cryogenic liquids by passing non-condensible gases through them is also being studied.

Heat Transfer. As heat transfer must be controlled and/or predicted in most cryogenic systems, there are a number of problems in this area which must be investigated. The current emphasis is on heat transfer from the atmosphere to surfaces at low temperature (from 20 to 90 °K). An experimental apparatus has been built for these studies. The surfaces can be held at 20 °K, 77 °K, or 90 °K; the air velocity can be varied up to 60 knots; the air temperature controlled between 0 and 100 °F; and the relative humidity controlled between 0 and 100 percent. The condensation of the components of air on the surfaces can be studied in detail. The formation of water frost on surfaces is being analyzed theoretically with the assistance of a high speed computer.

The behavior of liquid hydrogen under pressurization (up to 600 psia) and rapid outflow conditions is being investigated so that gas requirements and fluid conditions during pressurized transfers can be predicted. In connection with the cooldown studies, mentioned previously, as well as with



the condensation work, information on heat transfer between solid surfaces and cryogenic fluids is being obtained.

Cryogenic Equipment and Instrumentation. The growing use of cryogenic fluids in general, and liquid hydrogen in particular, has necessitated the development of some standard equipment and research into measurement problems. A standard coupling for use with vacuum-insulated hydrogen equipment is being developed in cooperation with the Air Force, the National Aeronautics and Space Administration, and the Atomic Energy Commission. Programs for the evaluation of pressure transducers at low temperatures, the determination of dynamic characteristics of temperature sensors, the measurement of liquid level, and the measurement of mass and volume flow rates are underway. A device for measuring the density of flowing fluids has been designed and is being perfected. A survey of the state of the art of cryogenic instrumentation has been completed.

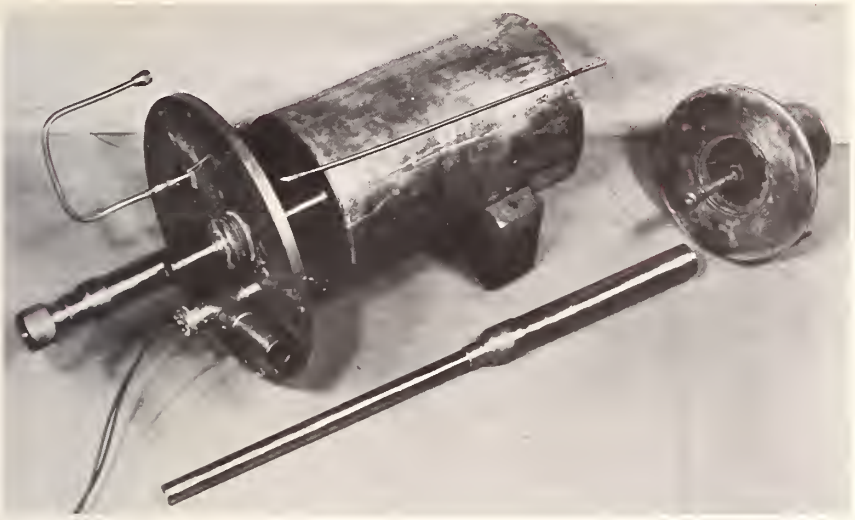
The most promising method for achieving very low pressures (those found in outer space) and high pumping speeds at these pressures is cryopumping. Cryopumps are being investigated to obtain information that will permit such systems to be designed. The experimental apparatus has been built and a reliable method for measuring pumping speeds has been developed.

Magnet Research. Problems associated with the production of high-intensity magnetic fields by means of low-temperature solenoids are being investigated. The results of these investigations will be used for thermonuclear power reactors, particle accelerators, and other applications where large volume high fields are required. A high-purity aluminum foil magnet has been designed and is nearing completion. It is designed to produce a steady-state field of 100,000 gauss in a cylindrical volume 3 in. in diameter by 8 in. long. The power requirement is anticipated to be only 4 kilowatts; the current will be only 135 amperes; and there will be forced-convection cooling with liquid hydrogen.

Low Temperature Seals. Last year the discovery of a method of using ordinary elastomeric O-rings to make excellent static seals at cryogenic temperatures was reported by the Bureau. These seals are now finding use in many types of cryogenic engineering applications. During the past year, methods have been found for making successful seals between flat flanges with O-rings, replacing the more cumbersome tongue and groove flange required previously.

Several pertinent physical properties, such as the thermal expansion of compressed elastomeric specimens as a function of temperature, are being measured. It is hoped that these measurements will provide data which will aid in predicting seal effectiveness.

Refrigeration Processes. During the past year, an experimental program was completed which made it possible to construct design charts to aid the analytical design of stable, externally-pressurized gas bearings. A miniature helium expansion turbine supported on gas bearings, designed in accordance with a method proposed by the Bureau, has been developed and



Disassembled view of apparatus for studying heat-transfer coefficients in liquid hydrogen systems. Studies are made of the heat-transfer processes occurring at the surface of the tube in the foreground under various conditions of temperature and heat flux. Heat transfer must be controlled and/or predicted in most cryogenic systems (page 145).

evaluated. The bearings have proven to be stable over a wide range of inlet pressure conditions.

Further computational work is being done on refrigeration methods suitable for use in the 2 to 30 °K region. Emphasis is being placed on process simplicity and reliability.

Consultation and Advisory Services. The Bureau is providing consultation on cryogenic engineering problems to the National Aeronautics and Space Administration in support of Projects Centaur and Rover. Both of these projects involve the use of liquid hydrogen propellants, and the Bureau's past experience in handling liquid hydrogen under a variety of conditions is being utilized. Support has been given to the principal contractors on these two programs in the areas of ground support equipment, insulation, low temperature seals, rolling element bearings, and low temperature window design. Attempts are being made to standardize hydrogen properties data and other pertinent properties of materials to aid in uniformity of analyses.

Cryogenic Engineering Data. The documentation unit of the Cryogenic Data Center is adding from 50 to 100 new literature references a week to the storage and retrieval system. Expansion of this acquisition effort is planned, as this number appears to be less than half of the articles of cryogenic interest currently being published. Recoding of a substantial portion of the reference listings has already been accomplished for conversion to mechanized storage and retrieval using the NBS Boulder computer facility. Upon completion of the recoding, an automated bibliography service will be provided to the cryogenic industry. There has been an increasing number of requests from the laboratory staff for literature procurement and from outside the laboratory for reports and data.

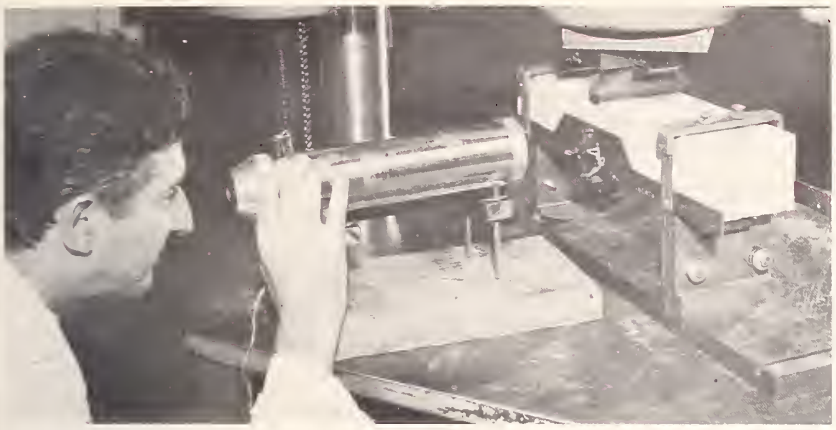
The selection and evaluation of thermodynamic data has continued at a somewhat accelerated rate. With the use of the large, high-speed computer, data from a great number of sources can be considered and a more accurate determination of "most probable values" can be made. In a three year period under sponsorship of Wright Air Development Division, two compendia of "Properties of Materials at Low Temperatures" (Phase I and Phase II) have been completed. Early in 1961 sponsorship was transferred to National Aeronautics and Space Administration and the work will be continued to cover additional properties of the same and other materials for which data are needed.

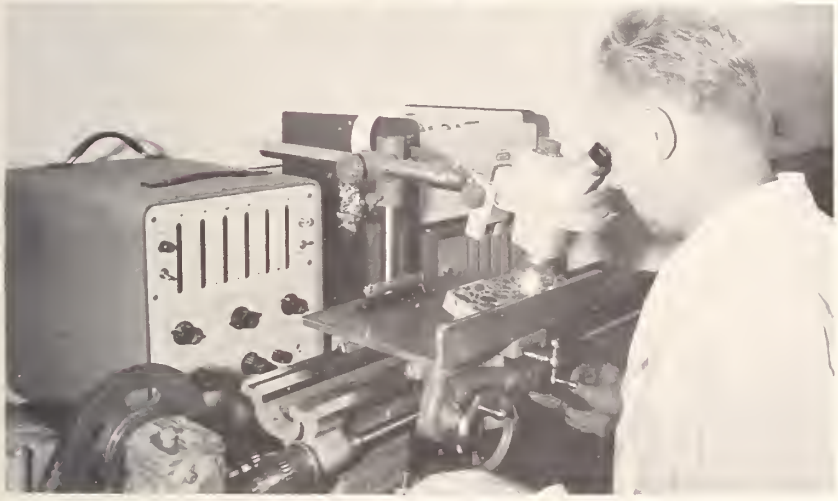
Gas Liquefaction. The increased availability of liquefied gases from commercial and other government sources permitted an appreciable reduction in gas liquefaction activities at the Boulder Laboratories. About 20,000 liters of liquid hydrogen were procured from other sources, making it necessary to liquefy only an additional 20,000 liters to take care of NBS laboratory needs. Similarly, some 360,000 liters of liquid nitrogen were purchased and only 190,000 liters produced with NBS facilities. As liquid helium is not yet generally available from commercial sources, the production of liquid helium remained about the same as for previous years, amounting to about 3,000 liters. The liquefaction facilities are being maintained in fully operable condition for production of liqefied gases whenever needed and on moderately short notice. The facilities are also being used for other programs of research and developments and for purification studies.

2.3.6. BUILDING RESEARCH

Advances and new developments in science and technology often can assist in solving problems related to building materials, structures, equipment and facilities. A major objective of the Bureau's building research program is therefore the development of new knowledge through research in chemistry, physics, and engineering. Another important objective is development of measurement and testing methods needed before some of the modern knowledge can be applied to the building industry. To facilitate the use of new knowledge, the Bureau provides aid to other laboratories by devising techniques for accurate measurements, by developing and supplying calibrated laboratory reference standards, and by participating in interlaboratory programs for checking the precision of measurements. The Bureau also provides advisory and consultative services on building problems to government agencies and others. It cooperates with public and private organizations in the formulation of specifications and national standards affecting the building industry.

During the year, various investigations looking to improved cement and concrete were carried forward. Creep and shrinkage of structural lightweight concretes were studied because of increasing interest in these materials. Meanwhile an apparatus was being developed to use electronic counters and a digital recorder to measure air voids in concrete, thus paving the way to increased durability.





Above: Measuring the deflection of a notched concrete prism during a study of the mechanism of crack propagation in reinforced concrete structures. Below: Determining the size and distribution of air voids in a polished, hardened concrete specimen. Air voids have a definite effect on the durability of concrete (page 150).

In other projects the mechanisms by which fires are extinguished were studied, as was the effectiveness of various fire retardants. Improved measuring techniques were sought for heat pumps and air conditioning units, and performance of air-to-air heat pumps was evaluated. With a view to protecting the perishable cargoes in refrigerated trailers, chilled air distribution inside these vehicles was investigated.

Several problems related to the moisture menace in construction were studied. An apparatus was constructed, and a method devised, for measuring water vapor permeance through building materials. The moisture problem in underground pipe insulation was studied, and test methods for moisture barrier materials for use in underground heat distribution systems were worked out. To combat moisture in flat insulated roofs as a threat

to economy and efficiency of air-conditioning and heating, roof specimens were studied and information obtained with which to prepare specifications for self-drying roofs.

Air Void Systems in Hardened Concrete. The quantity and distribution of entrained air in concrete is related to the production of durable concrete, and especially to the concrete's resistance to freezing and thawing and salt scaling. In this connection, knowledge of the amount and size distribution of air voids in the hardened concrete is essential for study of the mechanisms by which damage occurs and of the means to produce the more lasting concretes. To secure the needed knowledge, a linear-traverse apparatus is being developed, to enable polished specimens to be traversed under a microscope to determine the distribution of bubble sizes. Electronic counters and a digital recorder are used in the apparatus. When it is ready, work will commence on an automatic method for obtaining the bubble-size measurements, and this will mean saving in time and in operator fatigue.

Creep and Shrinkage of Structural Lightweight Concretes. In recent years expanded shale aggregates have been used extensively in reinforced concrete structures. In order to formulate satisfactory standards and design practices for lightweight aggregate concretes, in structures subjected to high sustained stresses, the Bureau conducted experiments on the creep and shrinkage in expanded shale concretes. This work is supported by the Expanded Shale Clay and Slate Institute. The creep properties are being determined for concretes of different strengths and different stress level-strength ratios. For purposes of comparison, parallel tests are being made on specimens of normal weight concretes.

Characterization of Cement Compounds by Infrared Spectroscopy. Infrared absorption spectra were obtained for a number of compounds which occur in portland cement, or are related to compounds formed in the hydration of portland cement. The patterns, in many cases, were found sufficiently distinctive to identify single phases. In addition, infrared was used to distinguish between water of crystallization and hydroxyl groups and to detect hydrogen bonding. Most of the stable combined water in the calcium silicate hydrates was found to be in the form of hydroxyl groups, and all of the calcium silicate hydrates showed some degree of hydrogen bonding.

Crack Propagation and the Fracture of Concrete. Knowledge of the mechanism of propagation of cracks in concrete is necessary for better understanding of the behavior of reinforced concrete structures. Experiments on the properties of concrete beams with crack-simulating notches indicated that the concept of a critical strain energy release rate being a condition for rapid crack propagation and consequent fracture was applicable to concrete. Estimates of critical strain energy release rates based on the locally elevated stress fields in the vicinity of a crack yielded values for beams with different notch depths which were in close agreement.

Calcium Aluminate Complex Salts. The complex compounds of calcium salts with tricalcium aluminate, important in the hydration, hardening, and durability of cements, were further investigated. A thermochemical study of calcium aluminate monocarbonate was completed, and one on the corresponding monosulfate and tricarbonate compounds is under way.

Extinguishment of Fires. Investigations were continued and expanded in regard to the mechanism by which extinguishing agents suppress combustion reactions. Experiments on extinguishment of diffusion flames by halogenated inhibitors gave results which appear to be more readily explained in terms of reactions, or other properties of the intact inhibitor molecules, than in terms of reactions of the halogen fragments obtained from the pyrolytic degradation of the inhibitor. A search of the literature revealed an unexpected correlation between the efficiency of an extinguishing agent and the yield of negative halogen ions produced in the dissociative resonance capture of low-energy electrons by inhibitor molecules. The subject is receiving further study.

Flammability of Materials. The radiant panel test for flammability, developed by NBS and recently adopted as an ASTM tentative method, was the subject of cooperative studies to determine its usefulness for evaluating performance of fire retardant and other paint systems. Data obtained indicate the method provides a sensitive way of measuring the relative effectiveness of paints in reducing surface flammability of the base material. Results show that when the paint is applied to a hardboard base, rather than to the commonly used fiberboard base, the test provides a superior method of measuring the paint's fire-retardant effectiveness. The study further indicates that commonly available alkyd or latex base paints, when applied at coverage rates in the range of 250 to 125 ft^2/gal, are effective fire retardants.

Heat Pump Studies. Experiments were conducted to improve measuring techniques for heat pumps and air-conditioning units, in which accurate determinations of average wet- and dry-bulb temperatures of a stream of moving air are required. An apparatus was built to study the principles and techniques for mixing a nonhomogeneous air stream for precise temperature measurement. This apparatus includes a means for providing a known degree of nonhomogeneity before the air stream enters the mixing device as well as precise measurements of the wet- and dry-bulb temperatures after the air stream leaves the mixing device. Performance data on orifices, baffles, screens, and rotating blades are being correlated with fluid mechanics theory to develop mixing devices that will provide more precise determinations of the "state condition" of an air stream. The suitability of thermometers, thermistors, and thermocouples for measuring dry-bulb temperatures in an air stream for a range of velocities from 300 to 2,000 ft/min was investigated.

Field Studies of Air-to-Air Heat Pumps. Field studies of air-to-air heat pumps were sponsored by the Office of the Chief of Engineers, the

Bureau of Yards and Docks, and the U.S. Air Force. The studies were carried out under summer and winter conditions in three housing projects of the Air Force. The purpose was to obtain data on performance factor, as well as on use of supplementary resistance heat, the contribution made to heating and cooling loads by the miscellaneous uses of energy in the houses, and the relation between computed and measured heating and cooling loads. Similar data on energy use in three other Air Force housing projects employing gas heating equipment and electric air-conditioning units were obtained for comparison.

Fundamental studies of the nature of combustion and the mechanisms of fire extinguishment are part of a broad fire research program. Here the effectiveness of a fire inhibitor is investigated (page 151).

Water Vapor Permeance of Building Materials. The building industry long has recognized that control of moisture and its migration in and through building materials is a major problem. However, present techniques for measurement of the permeance of water as vapor do not give results of sufficient precision. Therefore, there is a critical need for reference standards in this area and for test methods for making measurements consistent with established standards. With a view to this need an apparatus was constructed, and a method, based on an indirect gravimetric procedure, was devised to measure water vapor permeance. The method eliminates many errors and variables inherent in most procedures. The same basic equipment also can be adapted for study of radioactive tracer techniques, reducing the time for a single determination from days to minutes.

Two materials in film form were selected for possible reference samples. They were polyethylene terephtholate for low permeance, and polycarbonate film for higher permeance. Ultimately, it is expected the method and the reference samples can be used for the calibration of techniques and equipment in other laboratories.

Underground Heat Distribution Systems. Investigations of underground pipe insulation systems were essentially completed under the sponsorship of the Office of the Chief of Engineers, the Bureau of Yards and Docks, and the U.S. Air Force. The investigations revealed the necessity for long-term integrity of the moisture barriers used to protect the insulation. Moreover, the provision of air passages around or through the insulation to permit moisture removal by ventilation was demonstrated to be useful as an aid to protection and preservation of insulating materials.

An air-pressure test was recommended, to establish initially the absence of leaks in the moisture barrier of field installations, where free water is likely to be in contact with the heat-distribution system. Desirable physical characteristics and test methods for moisture barrier materials for use in underground heat distribution systems were worked out. A report on the investigation is being prepared for publication.

Moisture in Flat Insulated Roof Constructions. The actual insulating effect of insulated flat-roof constructions may depart greatly from the design values, due to moisture in the insulation. The moisture may be in the insulation when it is installed, or it may get into it later. As a result, the air-conditioning or heating of a building may be impaired, and the operating cost for these services may become excessive.

In an investigation sponsored jointly by the Office of the Chief of Engineers, Bureau of Yards and Docks, and U.S. Air Force over the past 5 years, tests of about 60 roof specimens under conditions simulating natural winter and summer roof exposures with daily solar heating were conducted. The results demonstrated that many common insulated flat-roof constructions are markedly reduced in insulating value by moderate amounts of moisture, and that under service conditions, substantial drying of wet constructions often is impracticably slow. However, some constructions were found to

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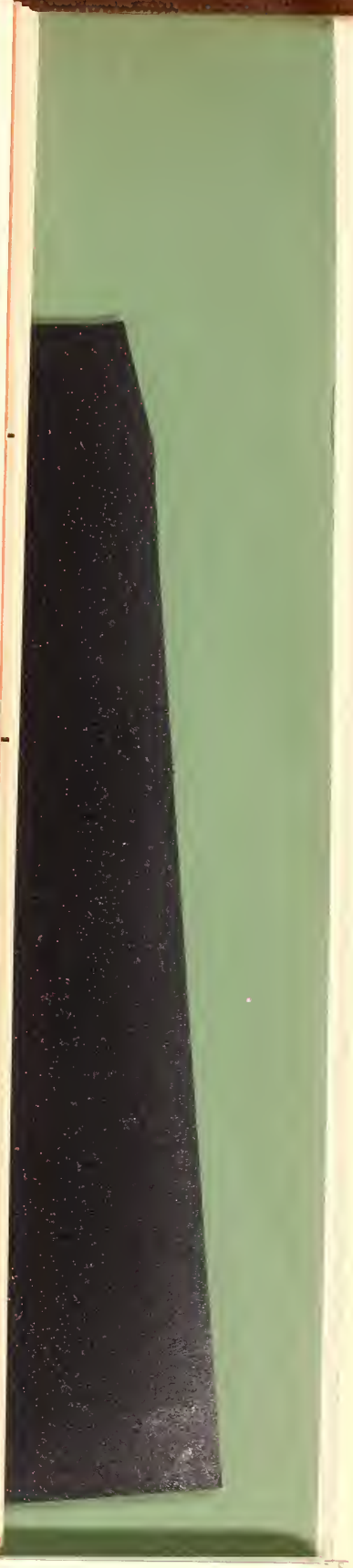


have good self-drying characteristics. The properties conducive to self-drying appear to be thermal conductivity, vapor permeability, moisture absorptive capacity, and possibly the hygroscopicity or capillarity of the component layers of roof construction, as well as their thickness and arrangement. Although investigations are continuing, sufficient information was obtained to prepare a specification for self-drying roof constructions.

Standards for Refrigerated Vehicles. A study of chilled air distribution inside refrigerated vehicles loaded with a closely-packed perishable cargo was supported in part by the U.S. Department of Agriculture. The study showed that the chilled air must circulate around the cargo and absorb the heat transmitted through the surrounding walls to protect the cargo adequately. Provision of sufficient air space for chilled-air circulation under the load was found to be the factor of greatest importance in improving the temperature distribution. The results further showed that the flow resistance of each parallel path for air flow must permit an air flow approximately proportional to the heat transmission into the corresponding part of the air circuit. It developed also that under favorable conditions there was little heat exchange between the chilled air and the cargo. The maximum temperature variation in the cargo was about equal to the temperature difference between the supply air from and return air to the cooling unit. This investigation is still in progress.

A related program, supported by the U.S. Department of Agriculture and the Truck Body and Equipment Association, was initiated to develop a testing and rating method for refrigerated trucks that would take into account the solar load and the heat transfer caused by intermittent opening of the doors in stationary vehicles.

Design Loads for Plumbing Systems. Analyses of experimental data on the hydraulics and pneumatics of plumbing drainage systems produced criteria aimed at providing pipes adequate to carry maximum expected loads, without being unnecessarily large and costly. The results indicate that substantial reductions in pipe sizes may be achieved safely in some cases. This research is related to main vertical drains and vents, and to horizontal drain systems.

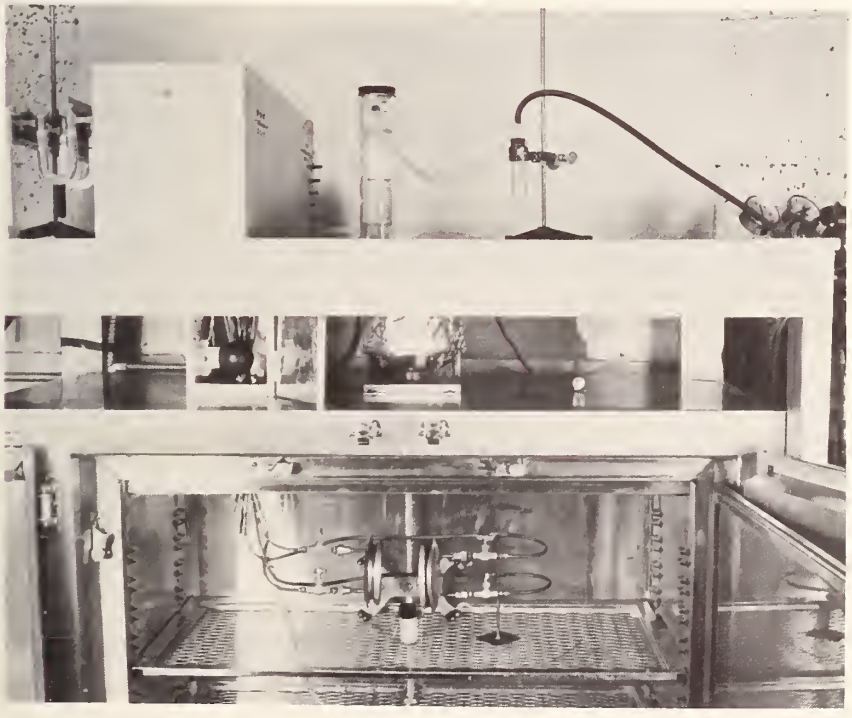
Advances in Thermal Conductivity Measurements. Many engineering undertakings involve measuring or increasing or limiting the flow of heat. For this reason, industry, research laboratories, and defense agencies need reliable data on thermal conductivity of materials ranging from insulators to highly conducting metals, at temperatures from the cryogenic range to 1,000 °C and higher. To meet these needs, the Bureau developed new and improved steady-state methods for measurement of conductivity, covering extended temperature ranges for a variety of materials. Thermal conductivity of these materials ranges from 0.00025 to 5 w/cm °C.

The different methods made possible thermal conductivity reference standards for other laboratories. Through such references, concordance of results can be confirmed or improved, and simpler apparatus used where reference standards for its calibration are available.

Organic Coatings Manual. With the advent of new synthetic resin binders and other components of coatings, a need for a modern organic coatings manual has arisen. Preparation of such a publication was undertaken, and it is now nearing completion. It will include discussions of specification products and information on late developments not yet covered by specifications.

Safety Codes. NBS actively participated in formulation of an Electrical Standard for Machine Tools, sponsored by the National Fire Protection Association. It was adopted as a tentative standard. Through membership on committees, NBS also cooperated in revision of codes developed under procedure of the American Standards Association. These included the National Electrical Code, sponsored by the National Fire Protection Association; the Safety Code for Building Construction, sponsored jointly by the American Institute of Architects, and the National Safety Council; and the Code for Protection Against Lightning, sponsored jointly by the National Fire Protection Association, The American Institute of Electrical Engineers and NBS.

Symposium on Chemistry of Cement. The Fourth International Symposium on the Chemistry of Cement was held at NBS from October 3d to 7th, 1960. It was sponsored jointly by the Bureau and the Portland Cement Association.



This apparatus, used with an indirect gravimetric procedure, was developed to measure water-vapor permeance of building materials (page 152).

Attendance at the symposia has increased from the 11 at the first (in London in 1918) to the 267 from 28 countries at the last. Meanwhile the proceedings have grown from 69 pages covering 10 papers and 5 discussions to 68 papers and 88 discussions requiring over 1,500 pages to be published by the Bureau in two volumes.

In attendance at the Washington meeting were outstanding research workers and leaders from this hemisphere and abroad. The meeting, in the manner of its predecessors, brought up to date the present state of knowledge of the chemistry of cement clinker, as well as the hydration of cement compounds and cements, the properties of cement pastes and concrete, the destructive processes in concrete, and the properties of special cements. It furnished an opportunity to take stock of progress made, and to assess needs for and direction of continuing research.

2.3.7. WEIGHTS AND MEASURES

One of the statutory responsibilities of the National Bureau of Standards is "cooperation with the States in securing uniformity in weights and measures laws and and methods of inspection." The responsibility of regulatory control over commercial weighing and measuring devices and commercial transactions involving quantity has been left by the Congress to the individual States. The Bureau contributes by offering consultative and advisory services to the States and calibration and physical adjustment of State reference weights and measures standards.

This program has been implemented through the Bureau's Office of Weights and Measures. The range of services is quite broad, including the development of (1) model weights and measures statutes, rules, and regulations, (2) properly designed and accurate physical standards of length, mass, and capacity, (3) effective procedures for testing commercial weighing and measuring devices, (4) specially designed testing equipment, (5) plans for systematic and effective quantity checking of prepackaged merchandise, (6) administrative procedures, (7) specifications and tolerances for commercial devices, (8) training schools for weights and measures officers, (9) visual aids, and (10) publications.

With the assistance of the Office of Weights and Measures, important amendments were made to existing weights and measures statutes in several States and completely new statutes were enacted in Alaska and Tennessee. Appropriate modernizing amendments were made in the Model State Law on Weights and Measures, the Model Package Regulation, and the Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices.

The national weights and measures training laboratory facility was completed and the first course for supervisory personnel of the States was successfully conducted. The requests for Bureau assistance in the conduct of technical training schools at the State level have greatly increased.

New equipment was designed specifically for the testing of large weighing scales, and liquid meters dispensing corrosive liquids, both pressure and nonpressure.

Studies were continued and recommendations to the States were made regarding equipment and procedures in the area of control of prepackaged commodities. It is now estimated by the U.S. Department of Agriculture that at least three-quarters of each retail food dollar is spent for packaged food. In addition, many other commodites are offered at retail in package form. With the tremendous increase in packaging, more and more weights and measures effort will undoubtedly be devoted to package control. A special study of the measurement practices in one of the nation's largest manufacturers of soaps and detergents resulted in a series of recommendations that are being placed into effect. These changes will lead to a much closer relation to the national measurement standards throughout the plants of that organization and may serve to guide the industry to greater accuracy in measurement activities.

A project covering new standards of weight and measure for the States is making excellent progress. In 1836 and 1866 the Congress provided the States with reference standards that became the basis for nationwide uniformity. Since then, through obsolescence and some individual purchases, nonuniformity in the physical characteristics of the standards has developed among the States. The Bureau's current efforts will provide a sound basis for repeating the 19th century actions. This would bring about complete uniformity among the States in weights and measures reference standards. An entirely new stainless steel has been developed commercially that provides excellent corrosion resistance, machinability, high-gloss finish, and the proper density for mass standards. Purchase and performance specifications for complete sets of such standards have been drawn, bids awarded, and prototype sets are now being fabricated. Three very special high precision balances of a design not heretofore applied to weight calibration have been constructed and are undergoing test. These balances are simple to manipulate, rapid to operate, and afford mass measurements with a precision of 1 part in 5 million (see p. 22).

Experimental studies on liquid-capacity standards molded of glass and of unusual design are nearing completion. Standards of this design will bring utility, versatility, and high precision to a State laboratory. In length standards, a highly useful length bench for testing rules, tapes, and the like has been designed, fabricated, and tested. This device, along with a yard-and-meter end standard and appropriate stainless tapes, will make available to a State laboratory for the first time precise test of various length-measuring instruments.

The Office of Weights and Measures has, as one of its basic responsibilities, the dissemination of accurate information on units, systems, and equivalents of weights and measures. Tables of interrelation in forms that facilitate ready reference are published, and a large volume of inquiries are handled

every year. Two collections of books and other documents make up the Weights and Measures Library—the archival collection and the reference collection. A complete indexing operation has been under way and is nearing completion. This library affords the staff and outside researchers and students complete references on the history and present status of weights and measures.

Traditionally, the National Conference on Weights and Measures has been one of the principal means of promoting uniformity and raising performance standards in weights and measures administration in the United States. Sponsored by the Bureau, the 46th Annual Conference was held in Washington, D.C., during the year. Thirty-five States, the District of Columbia, Puerto Rico, Canada, and Great Britain were officially represented at this 5-day meeting. The total registered attendance was 393.

3. APPENDIXES

3.1. ORGANIZATION OF THE NATIONAL BUREAU OF STANDARDS*

[The Bureau is headed by a Director who is appointed by the President with Senate confirmation. The Director is assisted by a Deputy Director, who is responsible for internal operations. Several Associate Directors participate in the leadership function, coordinating related technical work across division lines, heading important policy committees, and handling special assignments in a staff capacity. One of the Associate Directors, in addition to being responsible for administration and support activities of a continuing nature, is in charge of an extensive special project—planning for the Bureau's new laboratories which are being constructed at Gaithersburg, Maryland. In charge of the Boulder Laboratories is a Director who also has the status of Associate Director of the Bureau. Program activities are conducted in 22 scientific divisions. Most divisions correspond roughly to a major field of physical science or engineering, and are divided into sections responsible for technical areas within each field. Sixteen of the divisions are located in Washington and six in Boulder. Below the section level, the staff is organized into project groups which may be easily regrouped.]

DIRECTOR

ALLEN V. ASTIN

DEPUTY DIRECTOR

ROBERT D. HUNTOON

Associate Directors

C. M. HERZFELD — R. S. WALLEIGH

A. T. McPHERSON — EDWARD WICHERS

I. C. SCHOONOVER — W. A. WILDHACK

F. W. BROWN, Director, Boulder Laboratories

Assistants to the Director

W. S. BUSSEY
C. N. COATES

Special Research Group

H. P. BROIDA
U. FANO

Consultants to the Director

J. I. HOFFMAN
K. E. SHULER

Staff Advisers

NBS Reactor Program	C. O. MUEHLHAUSE
Financial Management Officer	N. L. CHRISTELLER
Legal Advisor	H. J. JOHNSON
Patent Advisor	D. ROBBINS

Director Emeritus

LYMAN J. BRIGGS

*As of September 1, 1961.

NBS WASHINGTON

SCIENTIFIC DIVISIONS AND SECTIONS

(In numerical order)

1. ELECTRICITY

Chief	C. H. Page
Resistance and Reactance	J. L. Thomas
Electrochemistry	W. J. Hamer
Electrical Instruments	F. M. Defandorf
Magnetic Measurements	I. L. Cooter
Dielectrics	J. D. Hoffman

2. METROLOGY

Chief	A. G. McNish
Assistant Chief	D. B. Judd
Photometry and Colorimetry	L. E. Barbrow
Refractometry	F. E. Washer
Photographic Research	C. S. McCamy
Length	B. L. Page
Engineering Metrology	I. H. Fullmer
Mass and Scale	A. G. McNish, *Acting*
Volumetry and Densimetry	J. C. Hughes, *Acting*

3. HEAT

Chief	C. M. Herzfeld, *Acting*
Assistant Chief for Thermodynamics	C. W. Beckett
Temperature Physics	J. F. Swindells
Heat Measurements	D. C. Ginnings
Cryogenic Physics	R. P. Hudson
Equation of State	J. Hilsenrath
Statistical Physics	M. S. Green

4. RADIATION PHYSICS

Chief	L. S. Taylor
X-ray	H. O. Wyckoff
Radioactivity	W. B. Mann
Radiation Theory	L. V. Spencer, *Acting*
High Energy Radiation	H. W. Koch
Radiological Equipment	S. W. Smith
Nucleonic Instrumentation	L. Costrell
Neutron Physics	R. S. Caswell

5. ANALYTICAL AND INORGANIC CHEMISTRY

Chief	H. C. Allen, Jr.
Assistant Chief	R. G. Bates
Consultants	R. Gilchrist
	C. P. Saylor
Pure Substances	F. L. Howard
Spectrochemistry	B. F. Scribner
Solution Chemistry	R. G. Bates
Standard Reference Materials	J. L. Hague
Applied Analytical Research	J. K. Taylor

6. 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

7. ORGANIC AND FIBROUS MATERIALS

Chief	G. M. Kline
Rubber	L. A. Wood
Textiles	H. F. Schiefer
Paper	R. B. Hobbs
Leather	J. R. Kanagy
Testing and Specifications	R. D. Stiehler
Polymer Structure	N. P. Bekkedahl
Plastics	F. W. Reinhart
Dental Research	W. T. Sweeney

8. METALLURGY

Chief	L. M. Kushner, *Acting*
Assistant Chief	T. G. Digges
Thermal Metallurgy	T. G. Digges
Chemical Metallurgy	L. L. Wyman
Mechanical Metallurgy	J. A. Bennett
Corrosion	G. A. Ellinger
Metal Physics	L. M. Kushner
Electrolysis and Metal Deposition	A. Brenner

9. MINERAL PRODUCTS

Chief	A. D. Franklin
Assistant Chief	C. H. Hahner
Consultants	R. F. Geller
	E. R. Lippincott
Engineering Ceramics	M. D. Burdick
Glass	C. H. Hahner
Refractories	*Vacant*
Enameled Metals	W. N. Harrison
Crystal Growth	F. Ordway
Physical Properties	A. D. Franklin, *Acting*
Constitution and Microstructure	H. F. McMurdie

10. BUILDING RESEARCH

Chief	D. E. Parsons
Consultant	W. F. Roeser
Structural Engineering	D. Watstein
Fire Research	A. F. Robertson
Mechanical Systems	P. R. Achenbach
Organic Building Materials	W. W. Walton
Codes and Safety Standards	R. L. Lloyd, *Acting*
Heat Transfer	H. E. Robinson
Inorganic Building Materials	R. L. Blaine

11. APPLIED MATHEMATICS

Chief	E. W. Cannon
Assistant Chief	F. L. Alt
Consultant	W. J. Youden
Numerical Analysis	P. Davis
Computation	D. I. Mittleman
Statistical Engineering	C. Eisenhart
Mathematical Physics	W. H. Pell
Operations Research	A. J. Goldman

12. DATA PROCESSING SYSTEMS

Chief	S. N. Alexander
SEAC	J. F. Rafferty
PILOT	P. D. Schupe
Research Information Center and Advisory Service on Information Processing	Miss M. E. Stevens
Components and Techniques	R. D. Elbourn
Computer Technology	J. A. Cunningham, *Acting*
Measurements Automation	J. A. Cunningham, *Acting*
Engineering Applications	S. N. Alexander, *Acting*
Systems Analysis	E. Glaser

13. ATOMIC PHYSICS

Chief	L. M. Branscomb
Consultant	F. L. Mohler
Spectroscopy	K. G. Kessler
Infrared Spectroscopy	E. K. Plyler
Solid State Physics	H. P. R. Frederikse
Electron Physics	L. L. Marton
Atomic Physics	S. J. Smith

14. 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

15. PHYSICAL CHEMISTRY

Chief	M. B. Wallenstein
Assistant Chief	F. Buckley
Thermochemistry	E. J. Prosen
Surface Chemistry	R. Klein
Organic Chemistry	H. S. Isbell
Molecular Spectroscopy	D. E. Mann
Molecular Kinetics	R. E. Ferguson
Mass Spectrometry	V. H. Dibeler

17. OFFICE OF WEIGHTS AND MEASURES

Chief M. W. Jensen

ADMINISTRATIVE AND SERVICE DIVISIONS

Office of Technical Information	W. R. Tilley
Accounting	J. P. Menzer
Personnel	G. R. Porter
Administrative Services	H. P. Dalzell
Shops	F. P. Brown
Supply	G. B. Kefover
Management Planning	I. Asay
Budget	J. E. Skillington
Internal Audit	J. Seidenberg
Plant	H. Graham
NBS Library	Miss S. Jones

BOULDER DIVISIONS

DIRECTOR, BOULDER LABORATORIES F. W. Brown

Consultants

Math-Analysis and Computation Facility Group	J. J. Sopka
Mathematical Physics and Education Director	E. H. Brown
Statistics	E. L. Crow
Astrophysics	R. N. Thomas
	J. T. Jeffries
Radio Wave Propagation	J. R. Wait
Physics of the Atmosphere	D. M. Gates
Communications Liaison Officer	Allen Barnabei
CRPL Liaison and Program Development	A. H. Shapley
Executive Officer and Chief of Administrative Division	S. W. J. Welch
Technical Information Officer	J. R. Craddock

81. CRYOGENIC ENGINEERING

Chief	R. B. Scott
Assistant Chief	B. W. Birmingham
Cryogenic Equipment	R. B. Jacobs
Cryogenic Processes	B. W. Birmingham
Properties of Materials	R. J. Corruccini
Cryogenic Technical Services	V. J. Johnson

82. *IONOSPHERE RESEARCH AND PROPAGATION

Chief	E. K. Smith, Jr.
Assistant Chief	T. N. Gautier
Assistant Chief	R. W. Knecht
Assistant to Chief for Technical Planning and Coordination	J. A. Kemper
Consultant	D. K. Bailey
Low Frequency and Very Low Frequency Research	A. G. Jean
Ionosphere Research	K. Davies
Prediction Services	W. B. Chadwick
Sun-Earth Relationships	R. W. Knecht
Field Engineering	H. G. Sellery
Radio Warning Services	J. V. Lincoln
Vertical Soundings Research	J. W. Wright

83. *RADIO PROPAGATION ENGINEERING

Chief	K. A. Norton
Assistant Chief for Research and Development	J. W. Herbstreit
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
Propagation-Terrain Effects	R. S. Kirby
Radio Meteorology	B. R. Bean
Lower Atmosphere Physics	M. C. Thompson, Jr.

84. RADIO STANDARDS

Chief	J. M. Richardson
Assistant Chief for Radio Frequencies	W. D. George
Assistant Chief for Microwave Frequencies	D. M. Kerns
Assistant Chief for Technical Planning and Coordination	E. C. Wolzien
Consultants	W. W. Brown
	P. F. Wacker
High-Frequency Electrical Standards	M. C. Selby
Radio Broadcast Service	A. H. Morgan
Radio and Microwave Materials	J. L. Dalke
Atomic Frequency and Time Interval Standards	R. C. Mockler
Electronic Calibration Center	H. W. Lance
Millimeter-Wave Research	L. Y. Beers, Acting
Microwave Circuit Standards	R. W. Beatty

85. *RADIO SYSTEMS

Chief	R. C. Kirby
Assistant Chief	D. W. Patterson
Consultant	G. W. Haydon
High Frequency and Very High Frequency Research	W. F. Utlaut
Modulation Research	W. C. Coombs
Antenna Research	H. V. Cottony
Navigation Systems	G. Hefley

87. *UPPER ATMOSPHERE AND SPACE PHYSICS

Chief	C. G. Little
Consultants	R. J. Slutz
	D. K. Bailey
Upper Atmosphere and Plasma Physics	R. M. Gallet
Ionosphere and Exosphere Scatter	K. L. Bowles
Airglow and Aurora	F. E. Roach
Ionospheric Radio Astronomy	R. S. Lawrence

*These divisions comprise the Central Radio Propagation Laboratory.

FIELD ESTABLISHMENTS

Visual Landing Aids Field Laboratory	Arcata, Calif.
Master Railway Track Scale Depot	Clearing, Ill.
Materials Testing Laboratories:	Allentown, Pa.
	Denver, Colo.
	San Francisco, Calif.
	Seattle, Wash.
Radio Transmitting Station WWV	Greenbelt, Md.
Radio Transmitting Station WWVL	Boulder, Colo.

Central Radio Propagation Laboratory Field Stations:

ALASKA
Anchorage
Barrow

ANTARCTICA
Marie Byrd Base**
Pole Station**
Mirny Base (Soviet)
Exchange Scientists with Byrd Base

AUSTRALIA
Cook**

BOLIVIA
La Paz**

BRAZIL, S.A.
Sao Jose dos Campos**

CANADA
Manitoba**

CHILE
Concepcion**

COLORADO
Beulah
Brighton
Chalk Cliff Site
Cheyenne Mtn.
Erie
Fritz Peak
Gunbarrel Hill
Haswell
Hygiene
Karval
Kendrick
Kolb
Lafayette
Marble
Marshall
Table Mesa
Sunset

COLOMBIA
Bogota**

GREENLAND
Thule**
Godhavn**
Narsarssuak**

HAWAII
Maui (WWVH)
Kekaha
Mt. Haleakala

ICELAND
Keflavik**
Reykjavik**

ILLINOIS
Long Branch

INDIA
New Delhi**

ISRAEL
Haifa**

JAPAN
Ohira**

KANSAS
Garden City

MALAYA
Singapore**

MOROCCO
Rabat**

NEBRASKA
Shickley

NIGERIA
Ibadan**

NORWAY
Andenes**

OKINAWA
Onna**
Okuma**

OKLAHOMA
Altus

PANAMA CANAL ZONE
Balboa**

PERU
Lima**
Jicamarca Radio Observatory

PHILIPPINE ISLANDS
Poro Point**
Baguio

PUERTO RICO
San Juan

SOUTH AFRICA
Pretoria**

SWEDEN
Enkoping**

UTAH
Salt Lake City**

VIRGINIA
Fort Belvoir
Front Royal
Sterling

WYOMING
Bill

**Contract or Mutual Cooperation.

3.2. SUMMARY OF NBS STAFF*

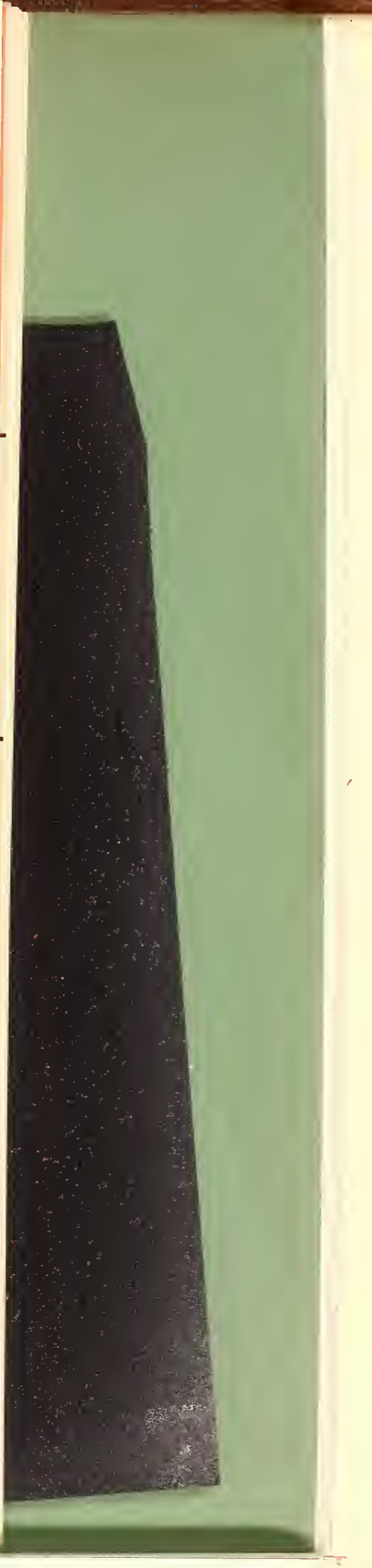
	Washington	Boulder	Total
Total permanent staff	2,253	1,020	3,273
Other staff**	457	189	646
Total on payroll	2,710	1,209	3,919
Research associates and guest workers	282	23	305
Total working at NBS	2,992	1,232	4,224
Professional staff:			
Physicists	515	237	752
Chemists	336	8	344
Engineers	232	192	424
Mathematicians	94	73	167
Other	150	35	185
Total professional staff	1,327	545	1,872

*As of June 30, 1961.
**WAE, full-time consultants, students, teachers, postdoctoral fellows, and temporary-limited employees.

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 1961:

Program and Source of Financing	Obligations Incurred (Rounded)		
Supported by NBS Appropriations:			
Operating Programs:			
Research & Technical Services		$19,578,000	
Construction and Facilities Program:			
Plant and Facilities	$2,976,000		
Construction of Facilities	10,430,000		
Subtotal		13,406,000	
Total NBS Appropriation			$32,984,000
Supported by Other Funds:			
Research and Development Programs:			
Other Federal Agencies	12,806,000		
Nongovernmental Sources	428,000		
		13,234,000	
Calibrations, Testing, and Standard Samples		4,892,000	
Reimbursable Administrative Services		1,134,000	
Total Supported by Other Funds			19,260,000
Total Program			52,244,000



The $19,578,000 program financed by the Bureau's Research and Technical Services appropriation reflects a continuation of the major program increase provided in 1960 and about a $1-million increase in salary costs due to the general pay raise.

The $2,976,000 expended in the Plant and Facilities program represents partial progress on several important facilities authorized in 1961, as well as completion of previously authorized facilities. The 1961 authorizations included the following:

(1) A new radio propagation research station near Lima, Peru, in which a 6 megawatt (peak power) radar transmitter and a 25-acre antenna array will be used to exploit the incoherent scatter technique for atmospheric research.
(2) A $1.2-million addition to the main laboratory building at Boulder, Colo.
(3) An atomic beam frequency standard.
(4) Design and engineering for a nuclear research reactor of the water-moderated, enriched-fuel type, to operate initially at a power level between 5 and 10 megawatts.

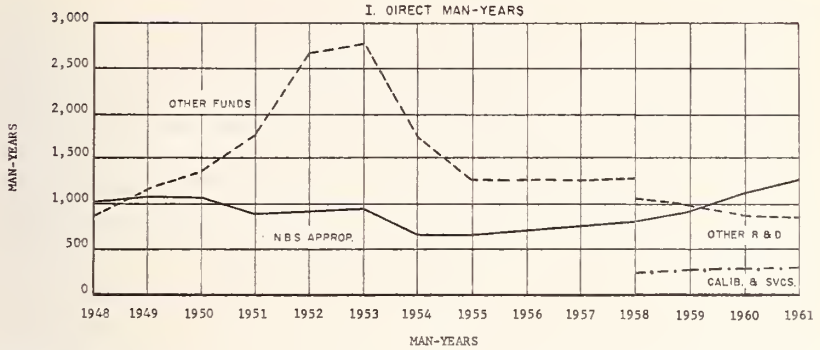
The construction of facilities obligations were for continued design effort on the new laboratories at Gaithersburg, Md., and for the construction contract for the first buildings: The Engineering Mechanics Laboratory and the Power Plant. Appropriations provided in 1961 will also finance the Radiation Physics Laboratory and the high-intensity linear electron accelerator.

Total Program Levels. For a number of years the Bureau has been attempting to achieve a more adequate level of effort on basic Bureau work and to reverse the imbalance between that work and work for other agencies. The following charts show the progress to date toward these objectives.

Chart I is perhaps the best index because it reflects the level of effort and is not distorted by changes in salary rates or other cost factors. The chart shows, for example, that in 1960 the research and development effort financed by the NBS appropriation finally rose above the 1950 level. It shows also that, since 1958, 50 percent of the increased effort on the Bureau's basic responsibilities has come from staff formerly financed by other agencies.

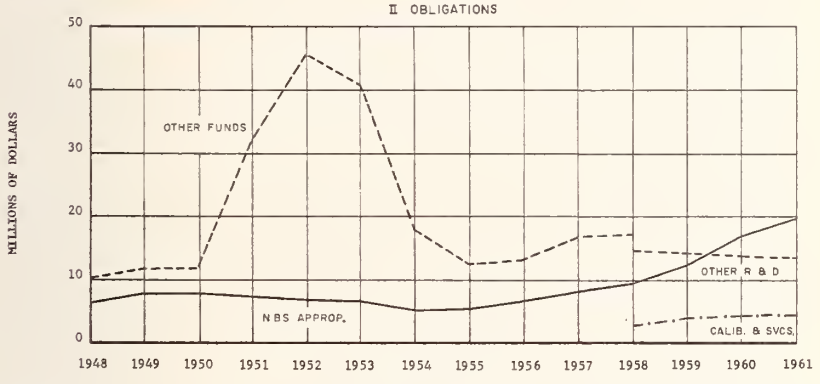
NBS TECHNICAL PROGRAM-COMPARISON OF SOURCES OF SUPPORT

I. DIRECT MAN-YEARS



	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
NBS APPROP	1004	1075	1071	896	914	947	672	669	710	776	822	928	1141	1299
OTHER R&D	849	1148	1371	1776	2664	2787	1730	1270	1284	1262	1056	974	861	821
CALIB & SVCS											244	283	296	313
TOTAL	1853	2223	2442	2672	3578	3734	2402	1939	1994	2038	2122	2185	2298	2433

II OBLIGATIONS



	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
NBS APPROP	6.5	7.9	7.9	7.5	7.1	7.0	5.3	5.6	6.9	8.2	9.7	12.4	17.1	19.6
OTHER R&D	10.1	11.7	11.6	31.7	45.6	40.6	18.1	12.6	13.1	16.9	14.8	14.2	13.7	13.2
CALIB & SVCS											2.8	3.9	4.2	4.6
TOTAL	16.6	19.6	19.5	39.2	52.7	47.6	23.4	18.2	20.0	25.1	27.3	30.5	35.0	37.4

3.4. ADVISORY COMMITTEES

STATUTORY VISITING COMMITTEE

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

DR. M. J. KELLY, Former President and Chairman of the Board, Bell Telephone Laboratories, Inc. (1962), Chairman
PROFESSOR F. SEITZ, University of Illinois (1961)
DR. LLOYD V. BERKNER, President, Graduate Research Center, Inc. (1963)
DR. CRAWFORD H. GREENEWALT, President, E. I. du Pont de Nemours & Co. (1964)
PROFESSOR CHARLES H. TOWNES, Columbia University (1965)

TECHNICAL ADVISORY PANELS

[Appointed by the National Academy of Sciences-National Research Council in cooperation with the leading scientific and technical societies to advise NBS Director in specific technical areas. Cooperating societies are: American Ceramic Society (ACerS); American Chemical Society (ACS); American Institute of Chemical Engineers (AIChE); American Institute of Electrical Engineers (AIEE); 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); Conference Board of the Mathematical Sciences (CBMS); and Institute of Radio Engineers (IRE). Appointments at large (AL). Members listed served during fiscal year 1961.]

DR. PAUL D. FOOTE, National Research Council, Executive Secretary

Advisory Panel to Electricity Division

PROF. W. A. LEWIS, Illinois Institute of Technology, Chairman (AIEE)
PROF. NORMAN I. ADAMS, JR., Yale University (AIP)
DR. WILLIAM G. AMEY, Leeds & Northrup Company (AIEE)
DR. RICHARD M. BOZORTH, Bell Telephone Laboratories (AIP)
DR. JOHN BRAINERD, University of Pennsylvania (IRE)
PROF. HENRY B. LINFORD, Columbia University (ACS)
MR. J. T. LUSIGNAN, The Ohio Brass Company (AIEE)
DR. ERNEST WEBER, Polytechnic Institute of Brooklyn (AIEE)

Advisory Panel to Metrology Division

DR. BRIAN O'BRIEN, Pomfret, Conn., Chairman (AIP)
PROF. ISAY A. BALINKIN, University of Cincinnati (ACerS)
PROF. CLARENCE E. BENNETT, University of Maine (AIP)
DR. ALSOPH H. CORWIN, The Johns Hopkins University (ACS)
MR. C. L. CROUCH, Illuminating Engineering Society (AL)
MR. A. M. DEXTER, Pratt and Whitney Company, Inc. (AL)
DR. ROBERT E. HOPKINS, Tropel, Inc. (AL)
MR. FLOYD W. HOUGH, Arlington, Virginia (ASCE)
MR. J. J. MORAN, Kimble Glass Company (ACerS)
MR. LOUIS POLK, The Sheffield Corporation (ASME)
PROF. JOHN STRONG, The Johns Hopkins University (AIP)
DR. J. H. WEBB, Eastman Kodak Company (AIP)

Advisory Panel to Heat Division

PROF. JOSEPH E. MAYER, University of California, Chairman (ACS)
PROF. JAMES A. BEATTIE, Massachusetts Institute of Technology (AIP)
PROF. HENRY A. FAIRBANK, Yale University (AIP)
PROF. JOSEPH KESTIN, Brown University (ASME)
DEAN R. B. LINDSAY, Brown University (AIP)
PROF. GLENN C. WILLIAMS, Massachusetts Institute of Technology (AIChE)

Advisory Panel to Radiation Physics Division

DR. H. M. PARKER, General Electric Company, Chairman (AIP)
DR. EVERITT P. BLIZARD, Oak Ridge National Laboratory (AIP)
DR. MARTIN DEUTSCH, Massachusetts Institute of Technology (AIP)
DR. A. O. HANSON, University of Illinois (AIP)
DR. WILLIAM A. HIGINBOTHAM, Brookhaven National Laboratory (IRE)
PROF. HAROLD A. LAMONDS, North Carolina State College (AIEE)
DR. LEONARD SCHIFF, Stanford University (AIP)

Advisory Panel to Analytical and Inorganic Chemistry Division

DR. T. IVAN TAYLOR, Columbia University, Chairman (ACS)
DR. CLARK E. BRICKER, Princeton University (ACS)
DR. N. D. COGGESHALL, Gulf Research and Development Company (AIP)
DR. W. D. COOKE, Cornell University (ACS)
DR. HERBERT A. LAITINEN, University of Illinois (ACS)
DR. W. WAYNE MEINKE, University of Michigan (ACS)
DR. J. R. RUHOFF, Malinckrodt Chemical Company (ACS)
DR. CHARLES E. WHITE, University of Maryland (ACS)

Advisory Panel to Mechanics Division

DEAN DANA YOUNG, Yale University, Chairman (ASME)
PROF. LYNN S. BEEDLE, Lehigh University (ASCE)
PROF. S. R. BEITLER, Ohio State University (ASME)
PROF. ARTHUR T. IPPEN, Massachusetts Institute of Technology (ASCE)
DR. HARRY F. OLSON, Radio Corporation of America (AIP)
PROF. JESSE ORMONDROYD, University of Michigan (ASME)
DR. MILTON PLESSET, California Institute of Technology (AIP)

Advisory Panel to Organic and Fibrous Materials Division

DR. NORMAN A. SHEPARD, Stamford, Conn., Chairman (ACS)
DR. J. H. DILLON, Textile Research Institute (AIP)
DR. MILTON HARRIS, The Gillette Company (ACS)
PROF. HERMAN F. MARK, Polytechnic Institute of Brooklyn (AIP)
DR. C. G. OVERBERGER, Polytechnic Institute of Brooklyn (ACS)
DR. J. F. DOWNIE SMITH, Carrier Research and Development Co. (ASME)

Advisory Panel to Metallurgy Division

MR. FRANCIS L. LAQUE, International Nickel Co., Chairman (ACS)
DR. D. J. DIENES, Brookhaven National Laboratory (AIP)
MR. A. R. LYTLE, Linde Company (AIME)
DEAN E. F. OSBORN, Pennsylvania State University (ACerS)
DR. JOSEPH A. PASK, University of California (ACerS)
DR. ALBERT J. PHILLIPS, American Smelting and Refining Co. (AIME)
MR. D. B. ROSSHEIM, M. W. Kellogg Corp. (ASME)

Advisory Panel to Mineral Products Division

MR. KARL SCHWARTZWALDER, General Motors Corp., Chairman (ACerS)
MR. HERBERT INSLEY, Washington, D.C. (ACerS)
DR. JAMES R. JOHNSON, Minnesota Mining and Manufacturing Co. (ACerS)
DR. NORBERT J. KREIDL, Bausch and Lomb Optical Co. (ACerS)
DEAN E. F. OSBORN, Pennsylvania State University (ACerS)
PROF. PIERCE SELWOOD, Northwestern University (ACS)
DR. ROBERT B. SOSMAN, Rutgers, The State University (ACerS)
PROF. BERTRAM E. WARREN, Massachusetts Institute of Technology (AIP)
DR. CLARENCE ZENER, Westinghouse Electric Corp. (AIME)

Advisory Panel to Building Research Division

DR. W. C. HANSEN, Valparaiso, Indiana, Chairman (ACS)
PROF. JESSE H. DAY, Ohio University (ACS)
PROF. ROBERT A. HECHTMAN, George Washington University (ASCE)
PROF. JAMES T. LENDRUM, University of Florida (AIA)
MR. PAUL V. JOHNSON, Structural Clay Products Research Foundation (ACerS)
DEAN WARREN L. MCCABE, Polytechnic Institute of Brooklyn (AICE)
DR. JOHN S. PARKINSON, Johns-Manville Products Corp. (AIP)
PROF. E. R. QUEER, Pennsylvania State University (AL)
MR. RAYMOND C. REESE, Toledo, Ohio (ASCE)

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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 1961.

RECIPIENT	AWARD
Ambler, Ernest	Arthur S. Flemming Award of the Junior Chamber of Commerce, Washington, D.C.
Astin, A. V.	Lifetime Honorary Membership by the Instrument Society of America
Bailey, Dana K.	The University of Arizona's Seventy-Fifth Anniversary Medallion of Merit
Brenner, Abner	Hothersall Memorial Lecturer 1961 of the Institute of Metal Finishing
	Blum Award from the American Electroplaters' Society
Briggs, Lyman J. (Director Emeritus)	The President's Citation from the Franklin Institute of the State of Pennsylvania for his loyal and valued services to the Institute
Davis, P. J.	National Academy of Sciences Annual Award for Scientific Achievement
Deitz, Victor R.	Achievement Award in Sugar Technology by the Sugar Industry Technicians
Douglas, Charles A.	Elected a Fellow in the Illuminating Engineering Society
Frederikse, H. P. R.	Fellowship from the John Simon Guggenheim Memorial Foundation
Havens, Clyde E.	Certificate of appreciation by the General Committee of the Division of Production of the American Petroleum Institute
Hayward, Evans	Fellowship from the John Simon Guggenheim Memorial Foundation
Kline, G. M.	Elected Director of the American Society for Testing Materials
Knudsen, Fred	Edgar Orton Award by American Ceramic Society
Koch, H. William	Alumnus of the Year, Queens College
Shapiro, Gustave	Elected a Fellow in the Institute of Radio Engineers
Sitterly, C. M.	Federal Woman's Award by Civil Service Commission
Wait, James R.	RESA Boulder Scientist Award

DEPARTMENT OF COMMERCE MERITORIOUS SERVICE AWARDS

RECIPIENT	TECHNICAL AREA
Cavallo, Lucy M.	Radiation physics
Christeller, Norman L.	Fiscal management
Cottony, Herman V.	Antenna research
Couch, Dwight E.	Electroplating metals and coatings
Cutkosky, Robert D.	Electrical measurements and standardization
Engen, Glenn F.	Microwave power standards
Glaze, Francis W.	Analytical chemistry
Grote, William	Instrument craftsmanship
Kipps, Charles B.	Procurement of supplies and equipment
Leslie, Robert T.	Fractional distillation
PoKempner, Minadora	Frequency allocation, frequency usage, and specifications for the design of communications equipment
Saylor, Charles P.	Microscopical techniques for the evaluation of pure substances
Smith, Jack C.	Textile physics
Torgensen, John L.	Growth of single crystals and mechanisms of purification
Wright, John W.	Ionospheric research
Joint Award:	
Greenspan, Martin	Physics of sound in water
Tschiegg, Carl E.	
Group Award:	
Chidester, Raymond	Mechanical support for the development of high precision instruments
Koepper, Walter	
Matway, John	
Stadler, William	

DEPARTMENT OF COMMERCE EXCEPTIONAL SERVICE AWARDS

RECIPIENT	TECHNICAL AREA
Bowles, Kenneth L.	Ionosphere and exosphere scatter
Branscomb, Lewis M.	Atomic processes of stellar atmospheres, the terrestrial ionosphere, and interplanetary space
Brown, Frederick W.	Administration of major scientific research programs
Craig, D. Norman	Accurate determination of the faraday
Digges, Thomas G.	Metallurgy
Mockler, Richard C.	Atomic frequency and time standards
Pararas, John	Unique extra high vacuum and very low temperature laboratory equipment
Roach, Franklin E.	Upper atmosphere physics
Schoonover, Irl C.	Materials research, program and organization planning, development and utilization of scientists

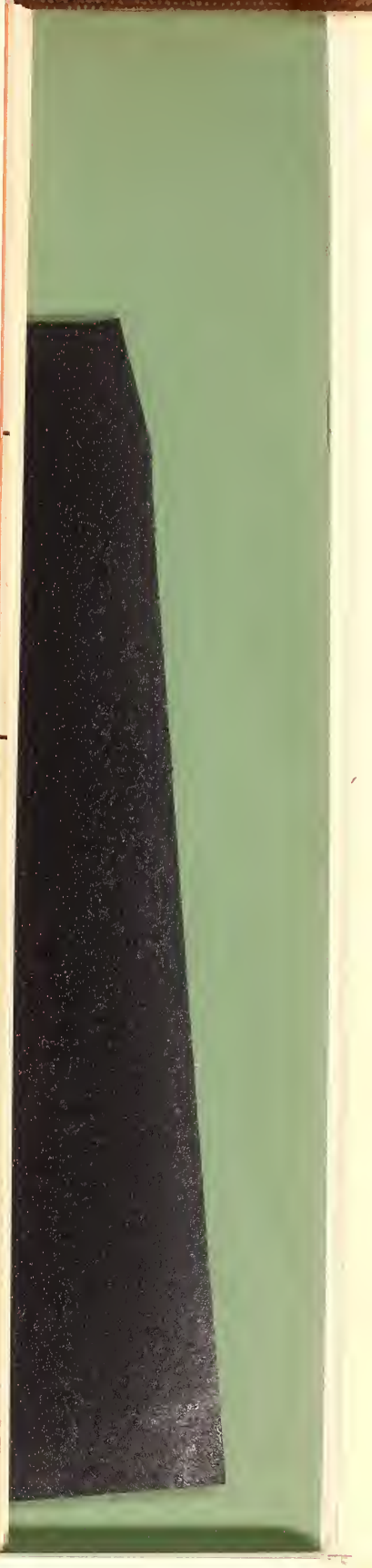
3.6. EDUCATION AND TRAINING PROGRAM

The Employee Development Program, oriented to the education and training needs of all staff members, is directed toward improving the skills and knowledge of the staff, increasing efficiency in the conduct of assigned duties, and preparing staff members in a systematic fashion for increased responsibilities. This program is implemented through two major educational media: the NBS Graduate School, and training through non-Government facilities. The program covers educational levels up through postdoctoral research and includes general staff development courses.

An average of 40 courses a year are offered in the curriculum of the NBS Graduate School, including graduate and undergraduate courses in the physical sciences, mathematics, and certain branches of engineering; and a series of scientific colloquia and seminars led by research leaders from the Bureau staff and from other research centers in this country and abroad. Educational counseling and a program of thesis accreditation are provided. A series of general staff development courses is also offered through the Graduate School. Typical courses in this category are scientific Russian, mathematical symbolism and terminology for clerical staff, and mechanical drawing.

The NBS Educational Committee determines course offerings through periodic need surveys. The curriculum is divided into NBS in-hours and NBS university-sponsored out-of-hours courses and is flexible to meet the varied and changing needs of the staff. For example, the Technician Career Program, established in 1960, helps to increase job efficiency and offers broader educational opportunities for subprofessional laboratory personnel.

Since the establishment of the Graduate School in 1908, more than 16,700 registrations have been recorded, and 272 graduate degrees have been awarded by 42 different universities, partly on the basis of credits obtained, or thesis work carried on, through the Graduate School. During the past year there were 1,217 registrations in 78 courses offered at the Washington and Boulder Laboratories. Of these registrations 560 were from the Army's Diamond Ordnance Fuze Laboratories and other government agencies in the Washington area.



Three major training programs are sponsored by the Bureau through non-Government facilities under authority of the Government Employees' Training Act of 1958. 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.

Non-Government facilities were used to train 262 staff members in 1961. Fourteen selected career scientists were sent on full-time research assignments to universities and research centers. Forty-one staff members, primarily scientists and subprofessional laboratory personnel, attended short concentrated courses and training programs at universities and in industry. In addition, 207 employees, largely from technical divisions, attended job-related courses at local educational facilities under the tuition reimbursement plan. The Bureau paid full salaries and expenses for participants in approved full-time non-Government training programs. These included tuition, related fees, travel, and per diem, as well as transportation of family and household effects for long-term training.

Each summer the Bureau sponsors a student trainee program open to college students majoring in the physical sciences, mathematics, and certain branches of engineering. An integrated work-study program, this activity includes lectures, tours, demonstrations, supervised laboratory assignments, and professional counseling. The purpose of the program is to acquaint young people with career opportunities in scientific research at NBS and to prepare select students for such careers. Approximately 220 students, representing 60 colleges and universities, participated in the 1961 summer student programs in Washington and Boulder; 130 of these were returnees from previous summers. The new group included eight outstanding high school students who had obtained recognition through the Westinghouse Science Talent Search or other national science competition.

The Bureau, in collaboration with the National Research Council, offers postdoctoral resident research associateships to young scientific investigators of unusual ability. Associates are given an opportunity for advanced training in basic research in the various branches of the physical and mathematical sciences. While acquiring basic knowledge, they have opportunities for developing new scientific approaches and laboratory skills, thus advancing scientific knowledge. Associateships are limited to 20 new appointments each year and are tenable at both the Washington and Boulder Laboratories.

Weekly Scientific Staff Meetings, which run 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, and are open to all professional staff members of the Bureau. They are also regularly attended by scientific personnel from neighboring laboratories. The lectures, which are designed to keep Bureau personnel abreast of current developments in the various fields, are given by members of the staff and by scientists from universities and other laboratories in the United States and abroad. Lectures by members of the Bureau staff include a yearly report to the staff by the Director, lectures on current research of broad general interest to other members of the staff, reports by staff members on international meetings, and reports from fellowship scientists on research work at other foreign and domestic institutions. About two-thirds of the program is devoted to lectures by guest scientists.

3.7. COOPERATIVE RESEARCH WITH INDUSTRY

The Bureau's Research Associate Plan, a cooperative program with American industry, has resulted in many significant developments in science and technology. Under this plan, technical, industrial, and commercial organizations can support work at the Bureau on projects that are of special interest to them, yet are of sufficient general interest to justify use of government facilities. These projects must also be important from the standpoint of the Nation's sum total of technological knowledge. Supporting industries donate both funds and personnel for the projects. At the present time 11 groups are supporting research associates at NBS in the following areas:

Sponsor	*Field of Activity*
American Dental Association	Dental research.
American Society for Testing Materials	Cement 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 Association	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.
Porcelain Enamel Institute	Development of standard tests.
Sinclair Oil Company	Thermoconductivity of thin films.

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

During the past year eight projects were supported by gifts from six organizations as follows:

Gift-Supported Projects

Donor	*Field of Activity*
American Iron and Steel Institute	Durability of steel pilings.
American Iron and Steel Institute	Ship plate steels.
American Iron and Steel Institute	Standard samples program.
Corrosion Research Council of the Engineering Foundation	Reactions at metal surfaces and on stress corrosion.
Edward Orton, Jr., Ceramic Foundation	Research in clays.
Expanded Shale, Clay and Slate Institute	Shale aggregate.
Georgetown University	Variable heart pump.
National Electrical Manufacturers Association	Refrigerator safety devices.

3.8. 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.
B. Mathematics and Mathematical Physics—issued quarterly.
C. Engineering and Instrumentation—issued quarterly.
D. Radio Propagation—issued six times a year.

The papers listed below have appeared in the four-section Journal since July 1960.

Volume 64A (Phys. and Chem.), No. 4 (July–Aug. 1960)

Gamma irradation of hexafluorobenzene, R. E. Florin, L. A. Wall, and D. W. Brown.

Behavior of isolated disturbances superimposed on laminar flow in a rectangular pipe, G. C. Sherlin.

Standard of spectral radiance for the region of 0.25 to 2.6 microns, R. Stair, R. G. Johnston, and E. W. Halbach.

Photovoltaic effect produced in silicon solar cells by X- and gamma rays, K. Scharf.

Phase equilibria in systems involving the rare-earth oxides. Part I. Polymorphism of the oxides of the trivalent rare-earth ions, R. S. Roth and S. J. Schneider.

Phase equilibria in systems involving the rare-earth oxides. Part II. Solid state reactions in trivalent rare-earth oxide systems, S. J. Schneider and R. S. Roth.

Some observations on the calcium aluminate carbonate hydrates, E. T. Carlson and H. A. Berman.

Acid dissociation constant and related thermodynamic quantities for triethanolammonium ion in water from 0 to 50 °C, R. G. Bates and G. F. Allen.

Ionization constants of four dinitrophenols in water at 25 °C, R. A. Robinson, M. M. Davis, M. Paabo, and V. E. Bower.

Dissociation constant of anisic (*p*-methoxybenzoic) acid in the system ethanol-water at 25 °C, E. E. Sager and V. E. Bower.

Preparation of sulfur of high purity, T. J. Murphy, W. S. Clabaugh, and R. Gilchrist.

Tritium-labeled compounds IV. D-glucose-6-*t*, D-xylose-5-*t*, and D-mannitol-1-*t*, H. S. Isbell, H. L. Frush, and J. D. Moyer.

Tritium-labeled compounds V. radioassay of both carbon-14 and tritium in films, with a proportional counter, H. S. Isbell, H. L. Frush, and N. B. Holt.

*Publications in these series are available, unless otherwise indicated, from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. For a discussion of the publications program see p. 18.

International practical temperature scale of 1948. Text revision of 1960, H. F. Stimson.
Evaluation of the NBS unit of resistance based on a computable capacitor, R. D. Cutkosky.
Wavelengths and intensities in the first spectrum of bromine, 2000 to 13000 A, J. L. Tech and C. H. Corliss.
Torsional resonance vibrations of uniform bars of square cross section, W. E. Tefft and S. Spinner.
Infrared studies of aragonite, calcite, and vaterite type structures in the borates, carbonates, and nitrates, C. E. Weir and E. R. Lippincott.
Dielectric properties of polyamides: polyhexamethylene adipamide and polyhexamethylene sebacamide, A. J. Curtis.
Heat of formation of calcium aluminate monocarbonate at 25 °C, H. A. Berman and E. S. Newman.
Thermodynamic constants for association of isomeric chlorobenzoic and toluic acids with 1,3-diphenylguanidine in benzene, M. M. Davis and H. B. Hetzer.
Heats of combustion and formation of trimethylborane, triethylborane, and tri-*n*-butylborane, W. H. Johnson, M. V. Kilday, and E. J. Prosen.
Pyrolysis of linear copolymers of ethylene and propylene, S. Straus and L. A. Wall.
Pyrolysis of fluorocarbon polymers, L. A. Wall and S. Straus.
Preparation of fluoro- and bromofluoroaryl compounds by copyrolysis of bromofluoralkanes, L. A. Wall, J. E. Fearn, W. J. Pummer, and R. E. Lowry.
Thermal stability of polydivinylbenzene and of copolymers of styrene with divinylbenzene and with tribinylbenzene, S. Straus and S. L. Madorsky.
Conformations of the pyranoid sugars. IV. Infrared absorption spectra of some fully acetylated pyranoses, R. S. Tipson and H. S. Isbell.
A standard for the measurement of the *p*H of blood and other physiological media, V. E. Bower, M. Paabo, and R. G. Bates.

Volume 64B (Math. and Math. Phys.), No. 3 (July–Sept. 1960)

Electric polarizability of a short right circular conducting cylinder, T. T. Taylor.
Distribution of quantiles in samples from a bivariate population, M. M. Siddiqui.
Split Runge-Kutta method for simultaneous equations, J. R. Rice.
A reduction formula for partitioned matrices, E. V. Haynsworth.
Selected bibliography of statistical literature, 1930 to 1957: III. Limit theorems, L. S. Deming.

Volume 64B (Math. and Math. Phys.), No. 4 (Oct.–Dec. 1960)

Magnetic polarizability of a short right circular conducting cylinder, T. T. Taylor.
Accuracy of Monte Carlo methods in computing finite Markov chains, N. W. Bazley and P. J. Davis.
Error bounds in the Rayleigh-Ritz approximation of eigenvectors, H. F. Weinberger.
Sequence transformations based on Tchebycheff approximations, J. R. Rice.
Numerical solution of the frequency equations for the flexural vibration of cylindrical rods, W. E. Tefft.

Volume 65B (Math. and Math. Phys.), No. 1 (Jan.–Mar. 1961)

On transient solutions of the "baffled piston" problem, F. Oberhettinger.
Special types of partitioned matrices, E. V. Haynsworth.
Bound for the *P*-condition number of matrices with positive roots, P. J. Davis, E. V. Haynsworth, and M. Marcus.
Some computational problems involving integral matrices, O. Taussky.
Computational problem concerning the Hilbert matrix, J. Todd.
Index to the distributions of mathematical statistics, F. A. Haight.
Selected bibliography of statistical literature, 1930 to 1957: IV. Markov chains and stochastic processes, L. S. Deming and D. Gupta.

Volume 65B (Math. and Math. Phys.), No. 2 (Apr.–June 1961)

Optimal approximation for functions prescribed at equally spaced points, H. F. Weinberger.
Truncations in the method of intermediate problems for lower bounds to eigenvalues, N. W. Bazley and D. W. Fox.

Comparison theorems for symmetric functions of characteristic roots, M. Marcus.
Some properties of the empirical distribution function of a random process, M. M. Siddiqui.
Another extension of Heinz's inequality, M. Marcus.
Mean motions in conditionally periodic separable systems, J. P. Vinti.
Some boundary value problems involving plasma media, J. R. Wait.
A new decomposition formula in the theory of elasticity, J. H. Bramble and L. E. Payne.
Pointwise bounds in the Cauchy problem of elastic plates, L. E. Payne.

Volume 64C (Eng. and Instr.), No. 3 (July–Sept. 1960)

A new method of measuring gage blocks, J. B. Saunders.
Gage blocks of superior stability: initial developments in materials and measurement, M. R. Myerson, T. R. Young, and W. R. Ney.
Variation of resolving power and type of test pattern, F. E. Washer and W. P. Tayman.
A multiple isolated-input network with common output, C. M. Allred and C. C. Cook.
Phase angle master standard for 400 cycles per second, J. H. Park and H. N. Cones.
Disturbances due to the motion of a cylinder in a two-layer liquid system, L. H. Carpenter and G. H. Keulengan.

Volume 64C (Eng. and Instr.), No. 4 (Oct.–Dec. 1960)

Error analysis of a standard microwave phase shifter, G. E. Schafer and R. W. Beatty.
A method of controlling the effect of resistance in the link circuit of the Thomson or Kelvin double bridge, D. Ramaley.
Automatic precise recording of temperature, G. S. Ross and H. D. Dixon.
Gimbal device to minimize the effects of off-center loading on balance pans, H. A. Bowman and L. B. Macurdy.
Response of microchemical balances to changes in relative humidity, H. E. Almer.
Chemical changes occurring during the weathering of two coating-grade asphalts, S. H. Greenfeld.
Characteristics of fifteen coating-grade asphalts, S. H. Greenfeld.

Volume 65C (Eng. and Instr.), No. 1 (Jan.–Mar. 1961)

Electronic scanning microscope for a spectrographic plate comparator, M. L. Kuder.
Viscoelastometer for measurement of flow and elastic recovery, R. J. Overberg and H. Leaderman.
An ultra low frequency bridge for dielectric measurements, D. J. Scheiber.
The Ephi system for VLF direction finding, G. Hefley, R. F. Linfield, and T. L. Davis.
Fast counting of alpha particles in air ionization chambers, Z. Bay, F. D. McLernon, and P. A. Newman.
X-ray diffraction measurement of intragranular misorientation in alpha brass subjected to reverse plastic strain, C. J. Newton and H. C. Vacher.
Enthalpy and specific heat of nine corrosion-resistant alloys at high temperatures, T. B. Douglas and A. C. Victor.
Determination of minor constituents in low-alloy steels by X-ray spectroscopy, R. E. Michaelis, R. Alvarez, and B. A. Kilday.

Volume 65C (Engr. and Instr.), No. 2 (Apr.–June 1961)

An experimental study concerning the pressurization and stratification of liquid hydrogen, A. F. Schmidt, J. R. Purcell, W. A. Wilson, and R. V. Smith.
Temperature dependence of elastic constants of some cermet specimens, S. Spinner.
Analog simulation of zone melting, H. L. Mason.
Residual losses in a guard-ring micrometer-electrode holder for solid-disk dielectric specimens, A. H. Scott and W. P. Harris.
A bolometer mount efficiency measurement technique, G. F. Engen.
Telescope for measurement of optic angle of mica, S. Ruthberg.
An automatic fringe counting interferometer for use in the calibration of line scales, H. D. Cook and L. A. Marzetta.

Relation of turbulence theory to ionospheric forward scatter propagation experiments, A. D. Wheelon.
Propagation at oblique incidence over cylindrical obstacles, M. P. Bachynski.
Diffraction by smooth conical obstacles, H. E. J. Neugebauer and M. P. Bachynski.
Characteristics of 488 megacycles per second radio signals reflected from the moon, B. C. Blevis and J. H. Chapman.
Tho use of polarization fading of satellite signals to study the electron content and irregularities in the ionosphere, C. G. Little and R. S. Lawrence.
Note on a test of the equivalence theorem for sporadic *E* propagation, J. W. Wright and T. N. Gautier.
Daytime attenuation rates in the very low frequency band using atmospherics, W. L. Taylor.
Measured electrical properties of snow and glacial ice, A. D. Watt and E. L. Maxwell.
Half-wave cylindrical antenna in a dissipative medium: current and impedance, R. King and C. W. Harrison.
Preface to ELF papers, J. R. Wait.
Some ELF phenomena, E. T. Pierce.
Mode theory and the propagation of ELF radio waves, J. R. Wait.
Studies of natural electric and magnetic fields, G. D. Garland and T. F. Webster.
Natural electromagnetic energy below the ELF range, W. H. Campbell.
Possible application of the system loss concept at ELF, K. A. Norton.
Measurements of the spectrum of radio noise from 50 to 100 cycles per second, M. Balser and C. A. Wagner.

Volume 64D (Radio Prop.), No. 5 (Sept.–Oct. 1960)

ELF electric fields from thunderstorms, A. D. Watt.
Field strength measurements in fresh water, G. S. Saran and G. Held.
Electrical resistivity studies on the Athabasca Glacier, Alberta, Canada, G. V. Keller and F. C. Frischknecht.
Amplitude distribution for radio signals reflected by meteor trails, A. D. Wheelon.
Computation and measurement of the fading rate of moon-reflected UHF signals, S. J. Fricker, R. P. Ingalls, W. C. Mason, M. L. Stone, and D. W. Swift.
On the theory of wave propagation through a concentrically stratified troposphere with a smooth profile, H. Bremmer.
Polarization and depression-angle dependence of radar terrain return, I. Katz and L. M. Spetner.
Methods of predicting the atmospheric bending of radio rays, B. R. Bean, G. D. Thayer, and B. A. Cahoon.
Loss in channel capacity resulting from starting delay in meteor-burst communication, G. R. Sugar.
Elementary considerations of the effect of multipath propagation in meteor-burst communication, G. R. Sugar, R. J. Carpenter, and G. R. Ochs.
Use of logarithmic frequency spacing in ionogram analysis, G. A. M. King.
Guiding of whistlers in a homogeneous medium, R. L. Smith.
Propagation of microwaves through a magneto-plasma, and a possible method for determining the electron velocity distributions, A. L. Cullen.
On electromagnetic radiation in magneto-ionic media, H. Kogelnik.
Radiation and admittance of an insulated slotted-sphere antenna surrounded by a strongly ionized plasma sheath, J. W. Marini.
A contribution to the theory of corrugated guides, G. Piefke.
High-gain, very low side-lobe antenna with capability for beam slewing, A. C. Wilson.
Shielding of transient electromagnetic signals by a thin conducting sheet, N. R. Zitron.
Cylindrical antenna theory, R. H. Duncan and F. A. Hinchey.

Volume 64D (Radio Prop.), No. 6 (Nov.–Dec. 1960)

URSI National Committee Report:
Commission 1. Radio measurement methods and standards
Commission 2. Tropospheric radio propagation
Commission 3. Ionospheric radio propagation
Commission 4. Radio noise of terrestrial origin
Commission 5. Radio astronomy
Commission 6. Radio waves and circuits
Commission 7. Radio electronics

Volnme 65D (Radio Prop.), No. 1 (Jan.–Feb. 1961)

Incoherent scattering by free electrons as a technique for studying the ionosphere and exosphere: some observations and theoretical consideration, K. L. Bowles.
Radio wave absorption of several gases in the 100 to 117 kMc/s frequency range, C. O. Britt, C. W. Tolbert, and A. W. Straiton.
On the theory of diffraction by a composite cylinder, R. D. Kodis.
An atlas of oblique-incidence ionograms (a digest), V. Agy, K. Davies, and R. Salaman.
A new approach to the mode theory of VLF propagation, J. R. Wait.
East-west effect on VLF mode transmission across the earth's magnetic field, D. Dobrott and A. Ishimaru.
Magneto-ionic propagation phenomena in low- and very-low-radiofrequency waves reflected by the ionosphere, J. R. Johler.
Correlation of monthly median transmission loss and refractive index profile characteristics, B. R. Bean and B. A. Cahoon.
Characteristics of waveguides for long-distance transmission, A. E. Karbowiak and L. Solymar.
Useful radiation from an underground antenna, H. A. Wheeler.
Observation of F-layer and sporadic-E scatter at VHF in the Far East, K. Miya, T. Sasaki, and M. Ishikawa.
A high-resolution rapid-scan antenna, H. V. Cottony and A. C. Wilson.

Volume 65D (Radio Prop.), No. 2 (Mar.–Apr. 1961)

Ionospheric motions observed with high-frequency back-scatter sounders, L. H. Tveten.
Relationship between red auroral arcs and ionospheric recombination, G. A. M. King and F. E. Roach.
Fresnel region fields of circular aperture antennas, M. K. Hu.
Free-balloon borne meteorological refractometer, J. F. Theisen and E. E. Gossard.
Weather and reception level on a troposphere link—annual and short-term correlations, L. G. Abraham, Jr., and J. A. Bradshaw.
Initial results of a new technique for investigating sferic activity, G. Hefley, R. H. Doherty, and R. F. Linfield.
Effect of antenna radiation angles upon HF radio signals propagated over long distances, W. F. Utlaut.
Graphical determination of radio ray bending in an exponential atmosphere, C. F. Pappas, L. E. Vogler, and P. L. Rice.
A formula for radio ray refraction in an exponential atmosphere, G. D. Thayer.
The impedance of a monopole antenna with a circular conducting-disk ground system on the surface of a lossy half space, S. W. Maley and R. J. King.
Radio-wave propagation in the earth's crust, H. L. Wheeler.

Volume 65D (Radio Prop.), No. 3 (May–June 1961)

Propagation studies using direction-finding techniques, E. C. Hayden.
Diversity effects in long distance high frequency radio pulse propagation, S. A. Bowhill.
Influence of ionospheric conditions on the accuracy of high frequency direction finding, P. J. D. Gething.
Phase difference observations at spaced aerials and their application to direction finding, W. C. Bain.
Research at the National Bureau of Standards applicable to long-distance location and direction-finding problems, R. Silberstein.
Design for spinning goniometer automatic direction finding, W. J. Lindsay and D. S. Heim.
Resolution characteristics of correlation arrays, I. W. Linder.
Instrumentation for propagation and direction-finding measurements, E. C. Hayden.
Brooke variance classification system for DF bearings, E. M. L. Beale.
Estimation of variances of position lines from fixes with unknown target positions, E. M. L. Beale.
Statistics of a radio wave diffracted by a random ionosphere, S. A. Bowhill.
Space analysis of radio signals, J. B. Smyth.
Effect of receiver bandwidth on the amplitude distribution of VLF atmospheric noise, F. F. Fulton, Jr.
Excitation of VLF and ELF radio waves by a horizontal magnetic dipole, J. Galejs.

Technical News Bulletin. This monthly publication summarizes the current research, development, and test activities of the Bureau. The articles are brief, with emphasis on the results of research and their significance, chosen for their importance to other scientists, engineers, and to industry. Résumés of longer research reports, important national and international conferences on fundamental science in which the Bureau has represented the Nation, and a bibliography of all publications by members of the staff as published are included. The Bulletin is designed to give a succinct account of the current work of the Bureau. (Annual subscription: domestic, $1.50; foreign, $2.25.)

Basic Radio Propagation 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 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: $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.

12. Stabilization of free radicals at low temperatures. $1.50.
17. New description of thorium spectra, R. Zalubas. 65 cents.
18. Heat treatment and properties of iron and steel, T. G. Digges and S. J. Rosenberg. 35 cents.
19. Atomic energy levels in crystals, J. L. Prather. 60 cents.
20. Ideal gas thermodynamic functions and isotope exchange functions for the diatomic hydrides, deuterides, and tritides, L. Haar, A. S. Friedman, and C. W. Beckett. $2.75.
21. Specific heats and enthalpies of technical solids at low temperatures. A compilation from the literature, R. J. Corruccini and J. J. Gniewek. 20 cents.
22. Climatic charts and data of the radio refractive index for the United States and the world, B. R. Bean, J. D. Horn, and A. M. Ozanich, Jr. $2.00.
23. Amplitude-probability distributions for atmospheric radio noise, W. Q. Crichlow, Q. D. Spaulding, C. J. Roubique, and R. T. Disney. 20 cents.
24. A spectrophotometric atlas of the spectrum of CH from 3000 A to 5000 A, A. M. Bass and H. P. Broida. 20 cents.
26. Development of high-temperature strain gages, J. W. Pitts and D. G. Moore. 20 cents.
27. Bibliography of temperature measurement, January 1953 to June 1960, C. Halpern and R. J. Moffat. 15 cents.
28. Causes of variation in chemical analyses and physical tests of portland cement, B. L. Bean and J. R. Dise. 25 cents.
29. Thermal expansion of technical solids at low temperatures. A compilation from the literature, R. J. Corruccini and J. J. Gniewek. 20 cents.
30. Corrected optical pyrometer readings, D. E. Poland, J. W. Green, and J. L. Margrave. 55 cents.

Circulars. Circulars are compilations of information on various subjects related to the Bureau's scientific and technical activities. They not only include the results of Bureau studies but give data of general interest from other sources. The Circular series was discontinued in June 1959. After this date, material that would formerly have been published in the Circular series has been largely directed to the Journal of Research and the new Monograph series.

510, Suppl. 2. Alphabetical index to tables of chemical kinetics. Homogeneous reactions. 35 cents.
539, Vol. 10. Standard X-ray diffraction powder patterns. H. E. Swanson, M. I. Cook, E. H. Evans, and J. H. deGroot. 40 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.

230. Standardization activities in the United States. A descriptive directory, S. F. Booth. $1.75.
231. Hydraulic research in the United States, 1960, H. K. Middleton. $1.00.
232. The metric system of measurement. 50 cents.

233. Units of weight and measure (United States customary and metric). Definitions and tables of equivalents, L. V. Judson. 40 cents.
234. Household weights and measures. 5 cents.
235. Report of the 45th national conference on weights and measures, 1960. 75 cents.
236. Standard frequencies and time signals from NBS stations WWV and WWVH. 10 cents.
237. Research highlights of the National Bureau of Standards, annual report 1960. 65 cents.
240. Publications of the National Bureau of Standards July 1, 1957, to June 30, 1960. (Includes titles of papers published in outside journals 1950 to 1959.) B. L. Arnold. $2.25.

Handbooks. These are recommended codes of engineering and industrial practice, including safety codes, developed in cooperation with the national organizations and others concerned. In many cases the recommended requirements are given official status through their incorporation in local ordinances by State and municipal regulatory bodies.
28. (1957)—Part III. Screw-thread standards for federal services 1957. 60 cents.
72. Measurement of neutron flux and spectra for physical and biological applications. 35 cents.
73. Protection against radiations from sealed gamma sources. 30 cents.
74. Building code requirements for reinforced masonry. 15 cents.
75. Measurement of absorbed dose of neutrons, and of mixtures of neutrons and gamma rays. 35 cents.
76. Medical X-ray protection up to 3 million volts. 25 cents.
77. Precision measurement and calibration. Vol. I. Electricity and electronics. $6.00; Vol. II. Heat and mechanics. $6.75; Vol. III. Optics, metrology, and radiation. $7.00.
78. Report of the International Commission on radiological units and measurements (ICRU) 1959. 65 cents.

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. They are available by purchase from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. (Order by PB number only.)
2–2 (PB151361–2) Supplementary world maps of F2 critical frequencies and maximum usable frequency factors, D. H. Zacharisen. $3.50.
18–3 (PB151377–3) Quarterly radio noise data—June, July, August 1959, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. $1.00.
18–4 (PB151377–4) Quarterly radio noise data—September, October, November 1959, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. $1.50.
18–5 (PB151377–5) Quarterly radio noise data—December, January, February 1959–60, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. $1.75.
18–6 (PB151377–6) Quarterly radio noise data—March, April, May 1960, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. $1.75.
18–7 (PB151377–7) Quarterly radio noise data—June, July, August 1960, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. $1.75.
18–8 (PB151377–8) Quarterly radio noise data—September, October, November 1960, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. $1.75.
18–9 (PB151377–9) Quarterly radio noise data—December, January, February 1960–1961, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. $1.75.
40–3 (PB151399–3) Mean electron density variations of the quiet ionosphere, May 3, 1959, J. W. Wright, L. R. Wescott, and D. J. Brown. $1.50.
55 (PB161556) Investigation of bearing creep of two forged aluminum alloys, L. Mordfin, N. Halsey, and P. J. Granum. $1.00.
59 (PB161560) Measurements and standards in plasma-physics and astrophysics at the National Bureau of Standards. $1.00.
60 (PB161561) Amplitude and phase of the low and very low-radiofrequency ground wave, J. R. Johler, L. C. Walters, and C. M. Lilley. 75 cents.
61 (PB161562) Proceedings of the 1960 conference on the propagation of ELF radio waves, J. R. Wait. 75 cents.
62 (PB161563) Rapid determination of the order of chemical reactions from time ratio tables, J. H. Flynn. $3.00.
63 (PB161564) Single scattered neutrons from an isotropic point source, E. R. Mosburg, Jr., and W. M. Murphey. 50 cents.
64 (PB161565) Design and operation of the Coilometer computer, P. Meissner. $2.00
66 (PB161567) Radio refractometry, J. W. Herbstreit. 50 cents.
67 (PB161568) On the nature of the crystal field approximation, K. Goldberg and C. M. Herzfeld. $2.50.

68 (PB161569) Transistorized building blocks for data instrumentation, J. A. Cunningham and R. L. Hill. $2.00.
69 (PB161570) Low- and very low-radiofrequency model ionosphere reflection coefficients, J. R. Johler, L. C. Walters, and J. D. Harper, Jr., $2.00.
70 (PB161571) Vapor pressures of organic compounds in the range below one millimeter of mercury, E. E. Hughes and S. G. Lias. 75 cents.
71 (PB161572) Calibration of five gamma-emitting nuclides for emission rate, J. M. R. Hutchinson. 75 cents.
72 (PB161573) Table of magnitude of reflection coefficient versus return loss ($L_R = 20 \log_{10} \frac{1}{|\Gamma|}$), R. W. Beatty and W. J. Anson. $1.25.
73 (PB161574) Some experiments on the deposition of gases at 4.2 °K, T. Braurer. $1.00.
74 (PB161575) Scattering of cobalt-60 gamma radiation in air ducts, C. Eisenhauer. 75 cents.
75 (PB161576) Soviet research in field electron and ion emission, 1955–1959; an annotated bibliography, T. W. Marton and R. Klein. $1.25.
76 (PB161577) ISOPAR. A new and improved symbolic optimizing assembly routine for the IBM 650, H. H. Howe. $1.50.
77 (PB161578) VHF and UHF power generators for RF instrumentation, A. H. Morgan and P. A. Hudson. 75 cents.
78 (PB161579) Oblique incidence receiving antenna array for a relative ionospheric opacity meter, A. C. Wilson. 50 cents.
79 (PB161580) VHF radio propagation data for Cedar Rapids-Sterling, Anchorage-Barrow, and Fargo-Churchill test paths, April 1951 through June 1958, G. R. Sugar and K. W. Sullivan. $4.00.
80 (PB161581) Bibliography of tropospheric radio wave scattering, R. L. Abbott. $2.25.
82 (PB161583) A survey of spread-*F*, F. N. Glover. $1.75.
83 (PB161584) On the scattering of γ rays by nuclei, U. Fano. 75 cents.
84 (PB161585) Bibliography on ionospheric propagation of radio waves (1923–1960), W. Nupen. $7.00.
85 (PB161586) A survey of computer programs for chemical information searching, E. C. Marden and H. R. Koller. $2.25.
86 (PB161587) The NBS meteor-burst propagation project—a progress report, C. E. Hornback, L. D. Breyfogle, and G. R. Sugar. $1.25.
87 (PB161588) A theoretical study of sporadic-*E* structure in the light of radio measurements, K. Tao. $1.25.
88 (PB161589) Prolonged space-wave fadeouts in tropospheric propagation, A. P. Barsis and M. E. Johnson. $2.00.

Publications in Outside Journals*

Achenbach, P. R., Drapeau, F. J. J., Phillips, C. W., Environmental factors in a family-size underground fallout shelter, Proc. Natl. Acad. Sci.-Natl. Research Council Meeting on Environmental Engineering in Protective Shelters, p. 69–118 (Feb. 1960).
Achenbach, P. R., Drapeau, F. J. J., Phillips, C. W., Studies of environmental factors in a family-size underground shelter, Report OCDM–NBS–60–1 issued by Office of Civil and Defense Mobilization (Mar. 1961).
Agy, V., Spiral patterns in geophysics, J. Atmospheric and Terrest. Phys. **19**, No. 2, 136–140 (1960).
Alexander, S. N., Trends in the technology of automatic data processing, AMA Report **41**, 38–42 (1960).
Allen, H. C., Jr., The structure of the vibrational-rotational bands of an asymmetric rotor, Phil. Trans. Roy. Soc. (London, England) [A] **253**, No. 1030, 335 (1961).
Allred, C. M., Cook, C. C., A precision RF attenuation calibration system, IRE Trans. Instrumentation **I–9**, No. 2, 268–274 (Sept. 1960).
Alt, F. L., Arithmetic, Handbook of Physics, Ed. by E. U. Condon and H. Odishaw, Ch. 1, Pt. 1, p. 1–4–1–9 (McGraw-Hill Book Co., Inc., New York, N.Y., 1958).
Alt, F. L., Computers, Encyclopedia of Chemistry Suppl., p. 91–92 (Reinhold Publ. Corp., New York, N.Y., 1958).
Alt, F. L., Electronic digital computers—their use in science and engineering, Book, Applied Mathematics and Mechanics **IV**, 336 (Academic Press, Inc., New York, N.Y., 1958).
Ambler, E., Methods of nuclear orientation, Book, Progress in Cryogenics **2**, 235–280 (Heywood and Co., Ltd., London, England, 1960).

*For completeness, a few references to publications issued previous to July 1959 are included.

Ambler, E., Some experimental aspects of nuclear orientation, Proc. Xth Intern. Congress of Refrigeration, Copenhagen, Denmark, 1959, Progress in Refrigeration in Science and Technology **I**, 195–198 (Pergamon Press, Inc., London, England, 1960).
Ambler, E., Dove, R. B., Continuously operating He^3 refrigerator for producing temperature down to ¼° K, Rev. Sci. Instr. **32**, No. 6, 737–739 (June 1961).
Arms, R. J., Pipberger, H. V., Stallman, F. W., Automatic screening of normal and abnormal electrocardiograms by means of a digital electronic computer, Proc. Soc. Experimental Biology and Medicine **106**, 130–132 (1961).
Armstrong, G. T., Marantz, S., The heat of combustion of dicyanoacetylene, J. Phys. Chem. **64**, 1776–1777 (1960).
Arp, V. D. Kropschot, R. H., Simple adiabatic demagnetization apparatus, Rev. Sci. Instr. **32**, 217–218 (Feb. 1961).
Arp, V. D., Kropschot, R. H., Superconducting magnetics, Proc. 1960 Cryogenic Eng. Conf., Book, Advances in Cryogenic Engineering **6**, Paper C–4, 166–173 (Plenum Press, Inc., New York, N.Y., 1961).
Arp, V. D., Kropschot, R. H., Wilson, J. H., Love, W. F., Phelna, R., Superconductivity of NB_3Sn in pulsed fields of 185 kilogauss, Phys. Rev. Letters **6**, No 9, 452–453 (Mar. 1, 1961).
Astin, A. V., Our measurement system and national needs, Sperryscope **15**, No. 6, 16–19 (1960).
Astin, A. V., Physical measurement-challenge to science and engineering, SPE J. **17**, No. 5, 455–458 (May 1961).
Astin, A. V., The role of Government research laboratories, Elec. Engr. **78**, No. 7, 738 (1959).
Ausloos, P., The effects of solvents on the gamma-ray radiolysis of methyl acetate and acetone, J. Am. Chem. Soc., **83**, No. 5, 1056–1060 (Mar. 1961).
Ausloos, P., Murad, E., The fluorescence and phosphorescence of trifluoroacetone vapor, J. Am. Chem. Soc. **83**, 1327 (1961).
Bailey, D. K., Ionospheric "forward" scattering, Proc. XIIIth Gen. Assembly of URSI (London, England, 1960), Natl. Acad. Sci.-Natl. Research Council Publ. Report No. 880, 281 (1961).
Bailey, D. K., Pomerantz, M. A., The cosmic ray increase of July 17, 1959, Can. J. Phys. **38**, 332–333 (1960).
Ballard, D. B., Use of the bulge test for determining the mechanical properties of stainless steel foil, Materials Research and Standards (ASTM Bull.) **1**, No. 6, 471–473 (June 1961).
Barger, R. L., Kessler, K. G., Sealed-off Hg^{198} atomic-beam light source, J. Opt. Soc. Am. **50**, No. 7, 651–656 (July 1960).
Barnes, J. A., Heim, L. E., A high-resolution ammonia-maser-spectrum analyzer, IRE Trans. Instrumentation **I–10**, 4–8 (June 1961).
Barnes, J. A., Mockler, R. C., The power spectrum and its importance in precise frequency measurements, IRE Trans. Instrumentation **I–9**, No. 2, 194–195 (Sept. 1960).
Barnes, M. W., Noyce, R. H., Inert enclosed pump for shaped flow of ultraclean solutions, Rev. Sci. Instr. **32**, No. 3, 353 (Mar. 1961).
Barone, J., Huff, R. L., Dickson, G., Surface roughness of dental gold castings, Dental Prog. **1**, No. 2, 78–84 (Jan. 1961).
Bates, R. G., Amine buffers for pH control, Ann. N.Y. Acad. Sci. **92**, 341 (1961).
Bates, R. G., Electrodes for pH measurements, J. Electroanalytical Chem. **3**, 93 (1961).
Bates, R. G., Electrometric pH determination, Chimica **14**, 111 (Apr. 1960).
Bates, R. G., The glass electrode, Book, Reference Electrodes, Ed. by D. J. G. Ives and G. J. Janz, ch. 5, p. 231–269 (Academic Press, Inc., New York, N.Y., 1961).
Bates, R. G., Guggenheim, E. A., Report on the standardization of *p*H and related terminology, Intern. Union Pure and Appl. Chem. **1**, No. 1, 163–168 (1960).
Bates, R. G., Hetzer, H. B., Dissociation constant of the protonated acid form of 2-amino-2-(hydroxymethyl)-1,3-propanediol [tris(hydroxymethyl) aminomethane] and related thermodynamic quantities from 0 to 50°, J. Phys. Chem. **65**, 667–671 (1961).
Bay, Z., Newman, P. A., Comparison of the ionization produced in air by alpha particles near 5 Mev and by beta particles, Radiation Research **14**, No. 5, 566–572 (May 1961).
Bay, Z., Newman, P. A., Seliger, H. H., Absolute measurement of W for Po^{210} alpha particles in air, nitrogen, and carbon dioxide, Radiation Research **14**, No. 5, 551–565 (May 1961).
Bay, Z., Seliger, H. H., Collection of ions produced by alpha particles in air, Phys. Rev. **120**, No. 1, 141–143 (Oct. 1, 1960).
Bean, B. R., Atmospheric bending of radio waves, Book, Electromagnetic Wave Propagation, p. 163–181 (Academic Press, Inc., N.Y., 1960).
Bean, B. R., Cahoon, B. A., Limitations of radiosonde punch-card records for radiometeorological studies, J. Geophys. Research **66**, No. 1, 328–331 (Jan. 1961).
Bean, B. R., Horn, J. D., Concerning the potential refractive index and the molecular refractivity, J. Meteorology **18**, No. 3, 427–428 (June 1961).

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Beatty, R. W., A microwave impedance meter capable of high accuracy, IRE Trans. Microwave Theory and Tech. Letter **MTT–8,** No. 4, 461–463 (July 1960).
Beatty, R. W., Engen, G. F., Anson, W. J., Measurement of reflections and losses of waveguide joints and connectors using microwave reflectometer techniques, IRE Trans. Instrumentation **I–9,** No. 2, 219–226 (Sept. 1960).
Bechtoldt, C. J., Vacher, H. W., Redetermination of the chromium and nickel solvuses in the chromium-nickel system, Trans. Metallurgical Soc., Am. Inst. Mining Engrs. **221,** 14–18 (Feb. 1961).
Beehler, R. E., Mockler, R. C., Snider, C. S., A comparison of atomic beam frequency standards, Nature **187,** No. 4738, 681–682 (Aug. 20, 1960).
Bender P. L., Atomic clocks for space experiments, Astronautics, p. 69–71 (July 1960).
Bennett, L. H., Budnick, J. I., magnetic resonance determination of the nuclear moment of tantalum-181 in $KTaO_3$, Phys. Rev. **120,** No. 5, 1812–1815 (Dec. 1960).
Bestul, A. B., Blackburn, D. H., Condensation coefficient of arsenic trioxide glass, J. Chem. Phys. **33,** No. 4, 1274–1275 (Oct. 1960).
Bienenstock, A., Determination of crystallite size distribution from X-ray line broadening, J. Appl. Phys. **32,** No. 2, 187–189 (Feb. 1961).
Birmingham, B. W., Chelton, D. B., Mann, D. B., Herandez, H. P., Cryogenic engineering of hydrogen bubble chambers, ASTM Bull. No. 240, 34 (TP164) (Sept. 1959).
Blackburn, D. H., An interferometric instrument for the rapid measurement of small diameters, Rev. Sci. Instr. **32,** No. 2, 137 (Feb. 1961).
Bloss, R. L., Evaluation of resistance strain gages at elevated temperatures, Materials Research and Standards (ASTM Bull.) **1,** No. 1, 9–15 (Jan. 1961).
Boischot, A., Lee, R. H., Warwick, J. W., Low frequency solar bursts and noise storms, Astrophys. J. **131,** No. 1, 61 (Jan. 1960).
Borkowski, R., Ausloos, P., Intramolecular rearrangements. I. *Sec*-butyl acetate and *sec*-butyl formate, J. Am. Chem. Soc. **83,** No. 5, 1053–1056 (Mar. 1961).
Bose, R. C., Connor, W. S., Analysis of fractionally replicated 2^m3^n designs, Bull. Inst. Intern. Stat. **XXXVII,** No. 3, 141 (1960).
Bouche, R. R., Improved standards for the calibration of vibration pickups, Exp. Mech. **1,** No. 4, 116–121 (Apr. 1961).
Bower, V. E., Paabo, M., Bates, R. G., A *p*H standard for blood and physiologic media, Clin. Chem. **7,** No. 3, 292 (1961).
Bower, V. E., Robinson, R. A., The ionization constants of 2-chloro-4-nitrophenol and 2-nitro-4-chlorophenol, J. Phys. Chem. **64,** 1078 (1960).
Bowles, K. L., Incoherent scattering by free electrons as a technique for studying the ionosphere and exosphere: some observations and theoretical considerations, p. 223–243 of AGARDograph 42, The Upper Atmosphere Above *F*2–Maximum. North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development, Avionics Panel. Papers presented at the Symp. of the Ionospheric Research Comm., Paris, France, May 1959.
Bowles, K. L., Cohen, R. S., Equatorial region ionospheric scatter research by the NBS during IGY, QST, p. 11–15 (Aug. 1957).
Boyd, A. E., Morris, E. E., Spatial distribution of energy dissipated by fallout beta-rays, Health Phys. **2,** 321–325 (Oct. 1960).
Brennan, J. A., Wilson, W. A., Radebaugh, R., Birmingham, B. W., Testing of ball bearings with five different separator materials at 9200 RPM in liquid nitrogen, Am. Soc. Mech. Engrs. No. 61–LUBS–18, 1–8 (Apr. 10, 1961).
Brenner, A., Electrodeless passage of direct current through an electrolyte, J. Electrochem. Soc. **107,** No. 12, 968–973 (Dec. 1960).
Brenner, A., Electrodeposition of metals from nonaqueous media, Ch. Encyclopedia of Chemistry and Technology 2d Suppl., p. 315–324 (Interscience Encyclopedia, New York, N.Y., Jan. 1961).
Bretemps, F. R., Saito, S., A transistor frequency meter, Electronic Ind. **19,** No. 10, 196–198 (Oct. 1960).
Brockman, J. R., Solar disturbances and radio communication forecasts, Syk and Telescope **XXI,** No. 6, 322–326 (June 1961).
Broida, H. P., Golden, S., Pressure dependence of rotationally perturbed lines in the ultraviolet band spectrum of CN, Can. J. Chem. **38,** 1666–1677 (1960).
Broida, H. P., Schiff, H. I., Sugden, T. M., Observations on the chemiluminescent reaction of nitric oxide with atomic oxygen, Trans. Faraday Soc. **57,** No. 458, 259–265 (Feb. 1961).
Brown, D. W., Wall, L. A., γ-irradiation of liquid and solid oxygen, Phys. Chem. **65,** 915 (1961).
Brown, D. W., Wall, L. A., Halobenzenes as sensitizers for the radiation induced polymerization of styrene, J. Polymer Sci. 44, 325–340 (June 1960).
Brown, E. H., On the properties of the vapor pressure curve, Cryogenics **1,** No. 1, 37–40 (Sept. 1960).

Budnick, J. I., Bennett, L. H., Nuclear magnetic resonance in tantalum metal, J. Phys. Chem. Solids **16,** No. ½, 37–38 (Jan. 12, 1960).
Bussey, H. E., Cavity resonator dielectric measurements of rod samples, Conf. Electrical Insulation (Annual Report of 1959), Natl. Acad. Sci.-Natl. Research Council Publ. **756,** 15 (1960).
Bussey, H. E., Standards and measurements of microwave surface impedance, skin depth, conductivity and Q, IRE Trans. Instrumentation **I–9,** No. 2, 171–175 (Sept. 1960).
Cameron, J. M., Digital techniques in statistical analysis of experiments, Handbook of Automation, Computation, and Control, Ed. By E. M. Grabbe, S. Ramo, D. E. Woolridge, Ch. 14, Sec. 4, p. 14–48–14–55 (John Wiley & Sons, Inc., New York, N.Y., 1958).
Campbell, W. H., Leinbach, H., Ionospheric absorption at times of auroral and magnetic pulsations, J. Geophys. Research **66,** No. 1, 25–34 (Jan. 1961).
Campbell, W. H., Rees, M. H., A study of auroral coruseations, J. Geophys. Research **66,** No. 1, 41–55 (Jan. 1961).
Carpenter, F. G., Deitz, V. R., A study of the chemical reactions in kilning bone char, Proc. 6th Tech. Session on Bone Char 1959, p. 321 (Bone Char Research Project Inc., Charlestown, Mass., 1961).
Carpenter, R. J., Beaty, E. C., Bender, P. L., Saito, S., Stone, R. O., A prototype rubidium vapor frequency standard, IRE Trans. Instrumentation **I–9,** No. 2, 132–135 (Sept. 1960).
Caswell, R. S., Neutron-insensitive proportional counter for gamma-ray dosimetry, Rev. Sci. Instr. **31,** No. 8, 869–871 (Aug. 1960).
Caul, H. J., Clabaugh, W. S., Susa, M. E., Procedure for the determination of the noble metal content of dental gold alloys, J. Am. Dental Assoc. **61,** No. 4, 439–443 (Oct. 1960).
Cavallo, L. M., The organization of international intercomparisons of radioactivity standards, with special reference to such measurements of NBS standards, Proc. Symp. Metrology of Radionuclides, IAEA, Vienna, Austria, p. 117 (1960).
Chadwick, W. B., Improvements in radio propagation prediction service, Elec. Engr. **79,** No. 9, 721 (Sept. 1960).
Chamberlain, J. W., Hunten, D. M., Rundle, H. N., Resonance scattering by atmospheric sodium VII. Measurement of the vertical distribution in twilight, J. Atmospheric and Terrest. Phys. **17,** 205–219 (1960).
Chapman, S., Geomagnetic storms and the space around the earth, Nature **187,** No. 4740, 824–827 (Sept. 3, 1960).
Chelton, D. B., Dean, J. W., Birmingham, B. W., Closed circuit liquid hydrogen refrigeration system, Rev. Sci. Instr. **31,** 712–716 (July 1960).
Chilton, C., VLF phase perturbations associated with meteor show ionization, J. Geophys. Research **66,** No. 2, 379–383 (Feb. 1961).
Chivers, H. J. A., Observed variations in the amplitude scintillations of the cassiopeia (23N5A) radio source, J. Atmospheric and Terrest. Phys. **19,** 54 (Sept. 1960).
Chivers, H. J. A., The simultaneous observation of radio star scintillations on different radio-frequencies, J. Atmospheric and Terrest. Phys. **17,** No. 3, 181–187 (1960).
Clabaugh, W. S., Reagent chemicals, Specifications prepared by the Committee on Analytical Reagents, Am. Chem. Soc. (1961).
Cleek, G. W., Scuderi, T. G., Evaluation of some oxide glasses for use as infrared materials, Proc. Infrared Information Symp. **5,** 4 (Aug. 1960).
Cohen, R. S., Bowles, K. L., On the nature of equatorial spread *F,* J. Geophys. Research **66,** No. 4, 1081–1106 (Apr. 1961).
Comeford, J., Gould, J., Infrared spectra of solid hydrocarbons at very low temperatures, J. Mol. Spectroscopy **5,** 474 (1960).
Connor, J. H., Lamb, V. A., Deposition of iron from salts of fluoro-acids, Plating **48,** No. 4, 388–389 (Apr. 1961).
Conrad, G. T., Jr., Newman, N., Stansbury, A. P., A recommended standard resistor-noise test system, IRE Trans. Component Parts **CP–7,** No. 3, 71–88 (Sept. 1960).
Cooper, J. W., Calculations of the neutron age in water and heavy water for D–D sources, Nuclear Sci. and Eng. **10,** No. 1, 1–10 (May 1961).
Cooper, J. W., The oscillator strength distribution of rare gas atoms calculated in a central potential model, 2d Intern. Conf. Physics of Electronic and Atomic Collisions, p. 7–10 (University of Colorado, Boulder, Colo., June 12–15, 1961).
Corliss, C. H., Meggers, W. F., Scribner, B. F., Residual arc spectra of seventy elements diluted in copper, Book, Colloquium Spectroscopicum Internationale **VIII,** 119–121 (1960).
Corruccini, R. J., Interpolation of platinum resistance thermometers, 20° to 273.15°K, Rev. Sci. Instr. **31,** 637–640 (June 1960).
Corruccini, R. J., Johnson, V. J., McIntosh, G. E., Scott, R. B., Cryogenics, ASRE Data Book, Refrigeration Applications, Ed. by V. J. Johnson, **1,** No. 1, Ch. 45, 45–01–45–22 (Am Soc. Refrig. Engrs., New York, N.Y., 1959).

Crow, E. L., An analysis of the accumulated error in a hierarchy of calibrations, IRE Trans. Instrumentation **I–9,** No. 2, 105–114 (Sept. 1960).
Culshaw, W., Resonators for millimeter and submillimeter wavelengths, IRE Trans. Microwave Theory and Tech. **MTT–9,** No. 2, 135–144 (Mar. 1961).
Curtis, A. J., Dielectric properties of polyamides, J. Chem. Phys. **34,** No. 5, 1849–1850 (May 1961).
Cutkosky, R. D., Shields, J. Q., The precision measurement of transformer ratios, IRE Trans. Instrumentation **I–9,** No. 2, 243–250 (Sept. 1960).
Dahl, S., Kaplan, A. M., 4-nitrophenyl esters, carbonates, and bis-carbonates as leather fungicides, J. Am. Leather Chemists Assoc. **55,** 480 (Sept. 1960).
Dannemiller, M. C., Zelen, M., Robustness of life testing procedures based on the exponential distribution, Technometrics **3,** No. 1, 29–49 (Feb. 1961); Missile Design and Development, p. 35–36 (Mar. 1961).
Davies, K., A study of 2-Mc/s ionospheric absorption measurements at high latitudes, J. Geophys. Research **65,** No. 8, 2285–2294 (Aug. 1960).
Davis, M. M., Paabo, M., Acid-base equilibria in benzene at three temperatures. The comparative reactivities of a phenolic acid and a carboxylic acid with triethylamine and with 1,3-diphenylguanidine, J. Am. Chem. Soc. **82,** 5081–5084 (1960).
Davis, P., Rabinowitz, P., Some SEAC computations of subsonic flows, Book, Bergman's Linear Integral Operator Method in the Theory of Compressible Fluid Flow, by M. Z. Krzywoblocki, p. 148–172 (Wien, Springer-Verlag, Berlin, Germany, 1960).
Deitz, V. R., Survey of variations in use for conducting laboratory-scale column filteration tests, Proc. 56th Tech. Session on Bone Char 1957, p. 237 (Bone Char Research Project Inc., Charlestown, Mass., 1959).
Dibeler, V. H., Reese, R. M., Franklin, J. L., Mass spectrometric study of cyanogen and cyanoacetylenes, J. Am. Chem. Soc. **83,** 1813–1818 (1961).
Digges, T. G., Research on light metals in the Metallurgy Division, NBS, India Tech. J. (Natl. Metals Lab., Jamshedpur, India), **III,** No. 1, 22 (Feb. 1961).
Douglas, T. B., Current thermodynamic research on light-element compounds at the National Bureau of Standards, Proc. Propellant Thermodynamics and Handling Conf., Spec. Rept. 12 (Ohio State University, Columbus, Ohio, June 1960).
Dressler, K., Schnepp, O., Absorption spectra of solid methane, ammonia, and ice in the vacuum ultraviolet, J. Chem. Phys. **33,** No. 1, 270–274 (July 1960).
Dunfee, B. L., A standard current transformer and comparison method—A basis for the establishing ratios of currents at audio frequencies, IRE Trans. Instrumentation **I–9,** No. 2, 231–236 (Sept. 1960).
Edlow, M. H., Plumb, H. H., Reproducibilities of carbon and germanium thermometers at 4.2°K, Proc. 1960 Cryogenic Conf., Book, Advances in Cryogenic Engineering **6,** Paper H–7, 542–547 (Plenum Press, Inc., New York, N.Y., 1961).
Ehrlich, M., The sensitivity of photographic film to 3-Mev neutrons and to thermal neutrons, Health Phys. **4,** No. 2, 113–128 (Dec. 1960).
Eisenhart, C., Some Canons of sound experimentation, Bull. Inst. Intern. Stat. **XXXVII,** No. 3, 339 (1960).
Eisenhart, C., Zelen, M., Elements of probability, Handbook of Physics, Ed. by E. U. Condon and H. Odishaw, Ch. 12, Pt. 1, p. 1–134–1–164 (McGraw-Hill Book Co., Inc., New York, N.Y., 1958).
Eisenhauer, C., Method for evaluating protection afforded by structures against fallout radiation, Proc. NRDL–OCDM Shielding Symp. (San Francisco, Calif., Oct. 31–Nov. 1, 1960).
Eisenhauer, C., Shielding calculations for civil defense, Health Phys. **4,** 129–132 (1960).
Eisenstein, J. C., Absorption spectrum and magnetic properties of osmium hexafluoride, J. Chem. Phys. **34,** 310–318 (1961).
Eisenstein, J. C., Magnetic properties and optical absorption spectrum of K_2ReCl_6, J. Chem. Phys. **34,** No. 5, 1628–1648 (May 1961).
Eisenstein, J. C., Spectrum of ReF_6, J. Chem. Phys. **33,** No. 5, 1530–1531 (Nov. 1960).
Engen, G. F., A method of improving isolation in multi-channel waveguide systems, IRE Trans. Microwave Theory and Tech. Letter **MTT–8,** No. 4, 460–461 (July 1960).
Engen, G. F., A transfer instrument for the intercomparison of microwave power meters, IRE Trans. Instrumentation **I–9,** No. 2, 202–208 (Sept. 1960).
Ericksen, J. L., Theory of anisotropic fluids, Trans. Soc. Rheology **IV,** 29–39 (1960).
Ernst, D. W., Ogburn, F., The nature, cause, and effect of porosity in electrodeposited coatings. VII. A microscopic examination of nickel coatings after atmospheric corrosion, Plating **48,** No. 5, 491–497 (May 1961).
Estin, A. J., Bussey, H. E., Errors in dielectric measurements due to a sample insertion hole in a cavity, IRE Trans, Microwave Theory and Tech. **MTT–8,** No. 6, 650–653 (Nov. 1960).

Estin, A. J., Trembath, C. L., Wells, J. W., Daywitt, W. C., Absolute measurement of temperature of microwave noise sources, IRE Trans. Instrumentation **I–9,** No. 2, 209–215 (Sept. 1960).
Fallona, J. F., Ferguson, H. I. S., Nicholls, R. W., An f/6 Littrow grating spectrograph, J. Opt. Soc. Am. **51,** 353 (1961).
Fang, P. H., Complex conductivity of some plasmas and semi-conductors, J. Appl. Research Soc. B (The Hagur), **9,** 51 (1960).
Fano, U., Introductory remarks, Conf. Electromagnetic Radiation, AFOSR **583,** 31–38 (University of Rochester, Inst. of Optics, Rochester, N.Y., Apr. 1961).
Fano, U., VI. Microscopic and macroscopic energy loss distributions. I. Theoretical reviews: a summary, Natl. Acad. Sci.-Natl. Research Council Publ. **752,** Rept. 29, 24 (Aug. 1960).
Fano, U., On a qualitative feature of photoionization spectra, 2d Intern. Conf. Physics of Electronic and Atomic Collisions, p. 10–11 (University of Colorado, Boulder, Colo., June 12–15, 1961).
Fano, U., Berger, M. J., Deep penetration of radiation (nuclear reactor theory), Proc. Symp. Applied Mathematics, p. 43 (1961).
Finegold, H., Structure of sulfurous esters, Proc. Chem. Soc. (London, England), p. 283–284 (Aug. 1960).
Fishburn, C. C., Mortars for cavity walls, Natl. Acad. Sci.-Natl. Research Council Publ. **793,** 37 (1960).
Florin, R. E., Wall, L. A., Brown, D. W., Free radicals in gamma-irradiated polystyrenes, Trans. Faraday Soc. **56,** No. 453, 1304–1310 (Sept. 1960).
Flynn, J. H., Smith, L. E., Comparative *p*H measurements on papers by water extraction and glass electrode spot tests, TAPPI **44,** No. 3, 223–228 (Mar. 1961).
Flynn, T. M., Pilot plant data for hydrogen isotope distillation, Chem. Engr. Progr. **56,** 37–42 (Mar. 1960).
Flynn, T. M., Studies of the low temperature distillation of hydrogen isotopes, Cryogenics 1, 96–100 (Dec. 1960); Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **6,** Paper D–8, 236–244 (Plenum Press, Inc., New York, N.Y., 1961).
Foster, B. E., Introduction and summary, Symp. Effects of Water-Reducing Admixtures and Set-retarding Admixtures on Properties of Concrete, Am. Soc. Testing Materials Spec. Tech. Publ. **266,** Introduction, p. 1–2 and Summary, p. 240–246 (June 1960).
Foster, B. E., Standards and testing, the key to quality, Eng. Bull. (Purdue University, Lafayette, Ind.), **XLIV,** No. 6, 54–62 (Nov. 1960).
Fowler, H. A., Non-reciprocity and time-reversal in microwave circuits, Academie royale de Belgique (Classe des Sciences) Koninklijke Acad. Van Belgie **46,** No. 11, 963-977 (Dec. 1960).
Fowler, H. A., Marton, L., Simpson, J. A., Suddeth, J. A., Electron interferometer studies of iron whiskers, J. Appl. Phys. **32,** No. 6, 1153 (June 1961).
Frankland, J. M., Physical metallurgy and mechanical properties of materials: ductility and the strength of metallic structures, J. Eng. Mech. Div., Proc. Am. Soc. Civil Eng. **86,** No. EM6, 45–52 (Dec. 1960).
Frederick, N. V., a vibrating sample magnetometer, IRE Trans. Instrumentation **I–9,** No. 2, 194–196 (Sept. 1960).
Friedman, D. C., Programming for a closed-loop, manned-machine combined system, Proc. Combined Analog-Digital Computer Systems Symp., Dec. 16–17, 1960, Philadelphia, Pa., 12th Article, p. 1–9 (Dec. 1960).
Frost, W. M., The strength of ten structural adhesives at temperatures down to —424° F, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5,** Paper H–1, 375–384 (Plenum Press, Inc., New York, N.Y., 1960).
Fuller, E. G., Hayward, E., Absorption and scattering of photons by holmium and erbium, Proc. Intern. Conf. Nuclear Structure (Kingston, Canada), p. 761–763 (Aug. 1960).
Fuller, E. G., Hayward, E., Scattering of photons by deformed nuclei, Proc. Intern. Conf. Nuclear Structure (Kingston, Canada), p. 763–766 (Aug. 1960).
Fuller, E. G., Hayward, E., The (γ ,n) cross section of lead and bismuth, Proc. Intern. Conf. on Nuclear Structure (Kingston, Canada), p. 941 (Aug. 1960).
Gallet, R. M., Utlaut, W. F., Evidence on the laminar nature of the exosphere obtained by means of guided high-frequency wave propagation, Phys. Rev. Letters **6,** No. 11, 591–594 (June 1, 1961).
Garriott, O. K., Little, C. G., The use of geo-stationary satellites for the study of ionospheric electron content and ionospheric radio-wave propagation, J. Geophys. Research **65,** No. 7, 2025–2027 (July 1960).
Gates, D. M., Near infrared atmospheric transmission to solar radiation, J. Opt. Soc. Am. **50,** No. 12, 1299–1304 (Dec. 1960).

Gates, D. M., Reply to criticisms concerning Ireland contained in article "Basic research in Europe", Science **128**, No. 3318, 1–9 (Aug. 1, 1958).
Gates, D. M., The physical environment as affected by radiattion, Proc. 50th Anniversary (University of Michigan, Ann Arbor, Mich., 1960).
Gates, D. M., Parker, J. M., Science news writing, Science **133**, No. 3477, 211–214 (Jan. 1961).
Gates, D. M., Shaw, C. C., The infrared transmission of clouds, J. Opt. Soc. Am. **50**, No. 9, 876–882 (Sept. 1960).
Geil, G. W., Carwile, N. L., Fracture characteristics of notched tensile specimens of titanium and titanium alloy, Materials Research and Standards (ASTM Bull.), **1**, No. 1, 16–21 (Jan. 1961).
Geller, S., Mantek, P., Tunnel diode large signal simulation study, Proc. IRE **49**, No. 4, 803 (Apr. 1961).
Geltman, S., Variational treatment of electron-hydrogen atom elastic scattering, Phys. Rev. **119**, No. 4, 1283–1290 (Aug. 15, 1960).
Ghaffari, A., On some partial differential equations of Brownian motion of a free particle (abstract), Proc. Intern. Conf. on Partial Differential Equations and Continuum Mechanics (University of Wisconsin, Madison, Wisc., June 7–15, 1960), p. 348–350 (1961).
Ghaffari, A., Some applications of Hardy's formula in Brownian motion (abstract), Am. Math. Soc. Notices **8**, No. 54, 238 (June 1961).
Ginnings, D. C., Standards of heat capacity and thermal conductivity, Book, Thermoelectricity, Chapt. 20, p. 320–341 (John Wiley & Sons, Inc., New York, N.Y., 1960).
Ginnings, D. C., The measurement of thermal conductivity, Book, Thermoelectric Materials and Devices, Chapt. 8, p. 113–132 (Reinhold Publ. Corp., New York, N.Y., 1960).
Gniewek, J. J., Corruccini, R. J., Carbon resistance thermometry with mixed dc and rf currents, Rev. Sci. Instr. **31**, No. 8, 899–900 (Aug. 1960).
Goldberg, K., Generating functions for formal power series in noncommuting variables, Proc. Am. Math. Soc. **11**, No. 6, 988–991 (Dec. 1960).
Goldberg, K., The minima of cyclic sums, J. London Math. Soc. **35**, 262–264 (1960).
Goodwin, R. D., Approximate wide-range equation of state for hydrogen. Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **6**, Paper G–4, 450–456 (Plenum Press, Inc., New York, N.Y., 1961).
Goodwin, R. D., An improved dc power regulator, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5**, Paper L–1, 577–579 (Plenum Press, Inc., New York, N.Y., 1960).
Gordon, R., Ausloos, P., Vapor-phase photolysis of formic acid, J. Chem. Phys. **65**, 1033 (1961).
Green, M. S., Comment on a paper of Mori on time-correlation expressions for transport properties, Phys. Rev. **119**, No. 3, 829–830 (Aug. 1960).
Green, M. S., On the theory of the critical point of a simple fluid, J. Chem. Phys. **33**, No. 5, 1403–1409 (Nov. 1960).
Green, M. S., Some applications of the generating functional of the molecular distribution functions, Book, Lectures in Theoretical Physics (Lectures delivered at the Summer Inst. for Theoretical Phys., University of Colorado, Boulder, Colo., 1960), **III**, 195–220 (Interscience Publ., Inc., New York, N.Y., 1961).
Green, M. S., Topological derivation of the Mayer density series for the pressure of an imperfect gas, J. Math. Phys. **1**, No. 5, 391–394 (Sept.–Oct. 1960).
Guntner, C. J., Reed, R. P., Mechanical properties of four austenitic stainless steels at temperatures between 300° and 20°K, Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **6**, Paper J–1, 565–576 (Plenum Press, Inc., New York, N. Y., 1961).
Hamer, W. J., Aircraft storage batteries, Appl. and Ind. **79**, Pt. II, 1–11 (Sept. 1960).
Hamer, W. J., Calomel electrode, Encyclopedia of Science and Technology **1**, 418 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).
Hamer, W. J., Electrodes, Encyclopedia of Science and Technology **1**, 371 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).
Hamer, W. J., Electromotive force (cells), Encyclopedia of Science and Technology **1**, 498 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).
Hamer, W. J., Glass electrode, Encyclopedia of Science and Technology **1**, 209 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).
Hamer, W. J., Hydrogen electrode, Encyclopedia of Science and Technology **1**, 549 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).
Hamer, W. J., Salt bridge, Encyclopedia of Science and Technology **1**, 18 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).
Hamer, W. J., Silver chloride electrode, Encyclopedia of Science and Technology **1**, 332 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).

Harman, G. G., Hard gallium alloys for use as low contact resistance electrodes and for bonding thermocouples into samples, Rev. Sci. Instr. **31**, No. 7, 717–720 (July 1960).
Harman, G. G., Some comments on the use and preparation of hard gallium, Rev. Sci. Instr. **32**, No. 4, 465–466 (Apr. 1961).
Harman, G. G., Raybold, R. L., Measurement of minority carrier lifetime in SiC by a novel electroluminescent method, J. Appl. Phys. **32**, No. 6, 1168–1169 (June 1961).
Harris, F. K., Cutkosky, R. D., Refining measurements by capacitance techniques, ISA—J. Instr. Soc. Am. **2**, 63–66 (Feb. 1961).
Haynsworth, E. V., Bounds for determinants with positive diagonals, Trans. Am. Math. Soc. **96**, 395–399 (1960).
Hayward, R. W., Pessoa, E. F., Hoppes, D. D., Van Lieshout, R., Gamma radiation from Zn^{63}, Il Nuovo Cimento **11**, 153 (1959).
Hebert, R. L., A study of two water resistance testers for shoe upper leather, J. Am. Leather Chemists Assoc. **55**, No. 7, 388–405 (July 1960).
Herbstreit, J. W., Highlights of the consultative committee on international radio (CCIR) activities in the field of radio propagation, 9th Plenary Assembly of CCIR, Proc. IRE **48**, No. 1, 45–53 (Jan. 1960).
Hermach, F. L., An analysis of errors in the calibration of electric instruments, Commun. and Electronics **54**, 1–6 (May 1961).
Hermach, F. L., Williams, E. S., Thermal voltage converters for accurate voltage measurements to 30 megacycles per second, Commun. and Electronics **49**, 200–206 (July 1960).
Herron, J. T., Rate of reaction of nitrogen atoms with ethylene, J. Chem. Phys. **33**, No. 4, 1273–1274 (Oct. 1960).
Herron, J. T., Dibeler, V. H., Mass spectra and appearance potentials of tetrafluorohydrazene, J. Chem. Phys. **33**, 1595 (1960).
Herzfeld, C. M., Goldberg, H., On the nature of the crystal field approximation, J. Chem. Phys. **34**, 643–651 (Feb. 1961).
Hilsenrath, J., Beckett, C. W., Benedict, W. S., Fano, L., Hoge, H. J., Masi, J. R., Nuttall, R. L., Touloukian, Y. S., Woolley, H. W., Book, Tables of thermodynamic and transport properties of air, argon, carbon dioxide, carbon monoxide, hydrogen, nitrogen, oxygen, and steam, 478 pages (Pergamon Press, Inc., Oxford, London, New York, and Paris, 1960).
Hiza, M. J., Cryogenic impurity adsorption from hydrogen, Chem. Engr. Prog. **56**, No. 10, 68–71 (Oct. 1960).
Hiza, M. J., Barrick, P. L., Cryogenic adhesive properties of bisphenol-*A* epoxy resins, SPE Trans. **1**, 73–79 (Apr. 1961).
Hiza, M. J., Kidnay, A. J., The adsorption of methane on silica gel at low temperatures, Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **6**, Paper G–5, 457–466 (Plenum Press, Inc., New York, N.Y., 1961).
Hoffman, J. I., Hydrogen sulfide precipitation of the elements from 0.2–0.5 normal hydrochloric acid, Chem.-Anal. **50**, No. 1, 30 and 32 (Mar. 1961).
Hoffman, J. I., Precipitation of the elements on addition of aqueous ammonia to their clear solution, Chem.-Anal. **49**, No. 3, 94 (Sept. 1960).
Hoffman, J. I., 8-quinolinol precipitation of the elements, Chem.-Anal. **49**, No. 4, 126 (Dec. 1960).
Hoppes, D. D., Ambler, E., Hayward, R. W., Kaeser, R. S., Matrix elements in the forbidden beta decay of Ce^{141}, Phys. Rev. Letters **6**, 115–118 (1961).
Horl, E., Marton, L., Electron diffraction studies on solid α-nitrogen, Acta Crystallographic **14**, Pt. 1, 11–19 (Jan. 1961).
Horowitz, E., Mandel, J., Capott, R. J., Boone, T. H., Evaluation of micrometer and microscopical methods for measuring thickness of floor coverings, Materials Research and Standards (ASTM Bull.), **1**, No. 2, 99–102 (Feb. 1961).
Hudson, P. A., A precision RF power transfer standard, IRE Trans. Instrumentation **I–9**, No. 2, 280–283 (Sept. 1960).
Hudson, R. P., Paramagnetic substances for nuclear orientation, Book, Progress in Cryogenics **3**, 99–127 (Heywood and Co., Ltd., London, England, 1961).
Hudson, R. P., Hosler, W. R., Magnetic susceptibility of cerous magnesium nitrate, Phys. Rev. **122**, No. 5, 1417–1420 (June 1961).
Hudson, R. P., Kaeser, R. S., Spin-lattice relaxation in cerous magnesium nitrate, Il Nuovo Cimento **19**, No. X, 1275–1277 (Mar. 16, 1961).
Hudson, R. P., Kaeser, R. S., Radford, H. E., Low temperature properties of cerous magnesium nitrate, Proc. VIIth Intern. Conf. Low Temperature Physics (University of Toronto, Canada), p. 45–48 (1960).
Hummer, D. G., Stebbings, R. R., Fite, W. L., Branscomb, L. M., Charge transfer and electron production in $H^- + H$ collisions, Phys. Rev. **2**, 668–670 (July 1960).

Hunt, D. C., Van Zandt, T. E., Photoionization heating in the *F* region of the atmosphere, J. Geophys. Research **66**, No. 6, 1673–1682 (June 1961).
Hunter, B. J., Kropschot, R. J., Schrodt, J. E., Fulk, M. M., Metal powder additives in evacuated-powder insulation, Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5**, Paper C–3, 146–156 (Plenum Press, Inc., New York, N.Y., 1960).
Isbell, H. S., Oxidation of alpha and beta-D-glucose with bromine Chem. and Ind. No. 18, 593 (May 1961).
Isbell, H. S., Frush, H. L., Holt, N. B., Absence of an isotope effect in the fractional recrystallization of alpha-D-glucose-l-*t*, Anal Chem. **33**, 225–226 (Feb. 1961).
Jackson, J. L., Electric field distribution in a dense plasma, Phys. of Fluids **3**, 927–931 (1960).
Jacobs, R. B., Martin, K. B., Hardy, R. J., Direct measurement of net positive suction head, J Basic Eng. **81**, 147–152 (June 1959).
Jefferies, J. T., Thomas, R. N., A comment on the NRL solar Lyman-Alpha results, Astrophys. J. **133**, No. 2, 606–607 (Mar. 1961).
Jefferies, J. T., Thomas, R. N., Source function in a non-equilibrium atmosphere. III. The influence of a chromosphere, Astrophys. J. **129**, No. 2, 401 (1959).
Jenkins, W. D., Willard, W. A., Youden, W. J., Stress-rupture tests at 1350° F on type 304 stainless steel, Materials Research and Standards (ASTM Bull.), **1**, No. 2, 104–108 (Feb. 1961).
Johannesen, R. B., Vanadium oxytrichloride (vandyl (V) chloride), Book, Inorganic Syntheses, Ed.-in-Chief, E. G. Rochow, **VI**, Chapt. 5B, No. 38, 119–120 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).
Johnson, V. J., The cryogenic data center, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5**, Paper K–8, 566–574 (Plenum Press, Inc., New York, N.Y., 1960).
Jones, F. E., Wexler, A., A barium film hygrometer element, J. Geophys. Research **65**, No. 7, 2087–2095 (July 1960).
Jones, W. B., Gallet, R. M., Ionospheric mapping by numerical methods, Telecomun. J. **12**, 260–264 (Dec. 1960).
Joseph, H. M., Two-oscillator scan stability, AIEE Trans. **78**, Pt. 1, 102 (Jan. 1960).
Judd, D. B., A five-attribute system of describing visual appearance, Am. Soc. Testing Materials Spec. Tech. Publ. **297**, 1–15 (1961).
Kahn, A. H., Electron scattering in high magnetic field, Phys. Rev. **119**, No. 4, 1189–1192 (Aug. 1960).
Kahn, A. H., Phase shift method for one-dimensional scattering, Am. J. Phys. **29**, 77 (1961).
Kanagy, J. R., The retannage of chrome-tanned leather with vegetable tannins, J. Am. Leather Chemists Assoc. **LVI**, No. 6, 252–272 (June 1961).
Kearsley, E. A., Bounds on the dissipation of energy in steady flow of a viscous incompressible fluid around a body rotating within a finite region, Arch. Rational Mech. and Analysis **5**, No. 4, 347–354 (1960).
Kearsley, E. A., Green, M. S., The foundations of mechanics and thermodynamics, Phys. Today **13**, No. 7, 22–25, (July 1960).
Keeler, R. N., Weitzel, D. H., Blake, J. H., Konecnik, M., A kinetics study of ortho-para hydrogen conversion, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5**, Paper K–1, 511–517 (Plenum Press, Inc., New York, N.Y., 1960).
Kiess, C. C., Corliss, C. H., Kiess, H. K., High-dispersion spectra of Jupiter, Astrophys. J. **132**, No. 1, 221–231 (July 1960).
Klebanoff, P. S., Evolution of amplified waves leading to transition in a boundary layer with zero pressure gradient, NASA Tech. Note D–195, 1 (Sept. 1959).
Klein, R., Scheer, M. D., Hydrogen atom reactions with propene at 77° K. Disproportionation and recombination, J. Phys. Chem. **65**, 324–325 (1961).
Klein, R., Scheer, M., Waller, J., The reaction of hydrogen atoms with solid propene at low temperatures, J. Phys. Chem. **64**, 1247–1250 (1960).
Knecht, R. W., On the possibility of detecting ionospheric drifts from occurrence of spread F echoes at low magnetic latitudes, Nature Letter **187**, No. 4741, 927 (Sept. 1960).
Knecht, R. W., Davies, K., Solar flare effects in the F region of the ionosphere, Nature **190**, No. 4778, 797–798 (May 1961).
Koch, J. W., Reception of space diversity transmitters, Wireless World (England) **65**, No. 10, 512 (1959).
Koch, J. W., Harding, W. B., Jansen, R. J., FM and SSB radiotelephone tests on a VHF ionospheric-scatter link during multipath conditions, IRE Trans. Commun. Systems **CS–8**, No. 3, 183–186 (Sept. 1960).

Knudsen, F. P., Parker, H. S., Burdick, M. D., Flexural strength of specimens prepared from several uranium dioxide powders; its dependence on porosity and grain size, and the influence of additions of titania, J. Am. Ceram. Soc. **43**, No. 12, 641–647 (Dec. 1960).

Kraus, M., Use of Gaussian orbitals for atoms-in-molecule calculations, J. Chem. Phys. **34**, No. 2, 692–693 (Feb. 1961).

Krishnamachari, S., Effect of molecular oxygen on the emission spectra of atomic oxygen-acetylene flames, J. Chem. Phys. **34**, 1709 (1961).

Kropschot, R. H., Multiple layer insulation for cryogenic applications, Cryogenics **1**, 171–177 (Mar. 1961).

Kropschot, R. H., Schrodt, J. E., Fulk, M. M., Hunter, B. J., Multiple-layer insulation, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5**, Paper D–2, 189–198 (Plenum Press, Inc., New York, N.Y., 1960).

Kruger, J., The oxide films formed on copper single crystal surfaces in water. II. Rate of growth at room temperature, J. Electrochem. Soc. **108**, No. 6, 503 (June 1961).

Lamb, V. A., Young, J. P., Plating gun bores, Ordnance **XLV**, No. 245, 725–727 (Mar.–Apr. 1961); Buchsenmacher **56**, No. 7, 130 (1961).

Lance, H. W., The nation's electronic standards program: Where do we now stand? IRE Trans. Instrumentation **I–9**, No. 2, 94–100 (Sept. 1960).

Laurie, V. W., Microwave spectrum of cis-difluoroethylene. Structures and dipole moments of fluoroethylenes, J. Chem. Phys. **34**, No. 1, 291 (1961).

Laurie, V. W., Microwave spectrum of isobutylene. Dipole moment, internal barrier, equilibrium conformation, and structure, J. Chem. Phys. **34**, No. 5, 1516–1519 (May 1961).

Leaderman, H., Schwarzl, F., Proposed nomenclature for linear viscoelastic behavior, Acta Rheologica **1**, No. 4/6, 674–676 (June 1961).

Leder, L., Suddeth, J. A., Characteristic energy losses of electrons in carbon, J. Appl. Phys. **31**, No. 8, 1422–1426 (Aug. 1960).

Lee, T. G., Robertson, A. F., Effectiveness of some powdered materials in extinguishing hydrocarbon fires, Natl. Acad. Sci.-Natl. Research Council Publ. **786**, 93–112 (June 1961).

Lehmann, F. A., Brauer, G. M., Analysis of pyrolyzates of polystyrene and poly(methyl methacrylate) by gas chromatography, Anal. Chem. **33**, No. 6, 673–676 (May 1961).

Levin, B. M., Stark, M. C., Tosini, P. E., Post office mechanization, Elec. Eng. **80**, No. 2, 105–172 (Feb. 1961).

Levin, E. M., Robbins, C. R., Waring, J. L., Immiscibility and the system lanthanium oxide-boric oxide, J. Am. Ceram. Soc. **44**, No. 2, 87–91 (Feb. 1961).

Lide, D. R., Jr., Dipole moments of hydrocarbons, J. Chem. Phys. **33**, No. 6, 1879 (Dec. 1960).

Lide, D. R., Jr., Microwave spectrum, structure, and dipole moment of propane, J. Chem. Phys. **33**, No. 5, 1514–1518 (Nov. 1960).

Lide, D. R., Jr., Structure of the isobutane molecule: Change of dipole moment on isotopic substitution, J. Chem. Phys. **33**, No. 5, 1519–1522 (Nov. 1960).

Lide, D. R., Jr., Christensen, D., An improved structure determination for vinyl fluoride, Spectrochim. Acta **17**, 665–668 (1961).

Lifson, S., Oppenheim, I., Neighbor interactions and internal rotations in polymer molecules. IV. Solvent effect on internal rotations, J. Chem. Phys. **33**, No. 1, 109–115 (July 1960).

Likins, R. C., McCann, H. G., Posner, A. S., Comparative fixation of calcium and strontium by synthetic hydroxyapatite, J. Biol. Chem. **235**, No. 7, 2152–2156 (July 1960).

Lincoln, J. V., Geomagnetic and solar data, J. Geophys. Research **65**, 7 (1960); **66**, 6 (1961).

Linnig, F. J., Tryon, M., Parks, E. J., Natural and synthetic rubbers: Review of Test methods, Anal. Chem. **33**, 127R (Apr. 1961).

Lippincott, E. R., Welsh, F. E., Weir, C. E., Microtechnique for the infrared study of solids, diamonds and sapphires as cell materials, Anal. Chem. **33**, 137–143 (Jan. 1961).

Lloyd, E. C., Johnson, D. P., Static and dynamic calibrations of pressure measuring instruments at the National Bureau of Standards, Automatic and Remote Control-Proc. 1st Intern. Congress of IFAC, p. 274–280 (1960).

Loebenstein, W. V., Regulated power supply for instruments, Electronics **33**, No. 48, 132 (Nov. 1960).

Logan, H. L., Studies of elevated temperature corrosion of type 310 stainless steel by vanadium compounds, Corrosion **17**, No. 4, 109–111 (Apr. 1961).

Lustig, E., A nuclear magnetic resonance study of syn-anti isomerism in ketoximes, J. Phys. Chem. **65**, 491 (1961).

McClintock, R. M., Warren, K. A., Tensile cryostat for the temperature range 4° to 300° K, Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **6**, Paper F–4, 372–378 (Plenum Press, Inc., New York, N.Y., 1961); Materials Research and Standards (ASTM Bull.), **1**, 95–98 (Feb. 1961).

McCulloh, K. E., Nickel oxide thin film resistors for low pressure shock wave detection, Rev. Sci. Instr. **31**, No. 7, 780–781 (July 1960).

McDonald, E. J., Report on sugars and sugar products, J. Assoc. Offic. Agric. Chemists **43**, 636 (1960).

McDonald, E. J., Foley, B. Y., Reducing sugar methods, J. Assoc. Offic. Agric. Chemists **43**, 645 (1960).

McKean, H. A., Mandel, J., Steel, M. N., A rating scale method for evaluating research positions, Personnel Admin. **23**, No. 4, 29–36 (July–Aug. 1960).

McKinney, J. E., Belcher, H. V., Marvin, R. S., The dynamic compressibility of a rubber-sulfur vulcanizate and its relation to free volume, Trans. Soc. Rheology **IV**, 347–362 (1960).

McLaughlin, W. L., Megaroentgen dosimetry employing photographic film without processing, Radiation Research **13**, No. 4, 594–609 (Oct. 1960).

McNesby, J. R., Kinetic isotope effect in the reaction of methyl radicals with ethane, ethane-d_6 and ethane 1, 1, 1-d_3, J. Phys. Chem. **64**, No. 11, 1671 (Nov. 1960).

McNesby, J. R., Scheer, M. D., Klein, R., Isotope effect in the hydrogen atom-formaldehyde reaction, J. Chem. Phys. **32**, No. 6, 1814–1817 (June 1960).

McNish, A. G., Nomenclature for standards of radioactivity, Intern. J. Appl. Radiation and Isotopes **8**, 145–146 (Jan. 1960).

McNish, A. G., Cameron, J. M., Propagation of error in a chain of standards, IRE Trans. Instrumentation **I–9**, No. 2, 101–104 (Sept. 1960).

McPherson, A. T., New standards for the space age, Astronautics **6**, No. 1, 24–25; 50–54 (Jan. 1961).

Madorsky, S. L., Straus, S., Stability of thermoset plastics at high temperatures, Modern Plastics **38**, 134–140 (Feb. 1961).

Malitson, H. H., Purcell, J. D., Tousey, R., Moore, C. E., The solar spectrum from 2635 to 2085A, Astrophys. J. **132**, 746 (1960).

Mandel, J., Analytical laboratory problems, Trans. Metropolitan Conf., Am. Soc. Quality Control, p. 99–107 (Feb. 1960).

Mandelkern, L., The dependence of the melting temperature of bulk homopolymers on the crystallization temperature, J. Polymer Sci. **47**, 494–496 (July 1960).

Mann, D. B., Bjorklund, W. R., Macinko, J., Hiza, M. J., Design, construction, and performance of a laboratory-size helium liquefier, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5**, Paper G–5, 346–353 (Plenum Press, Inc., New York, N.Y., 1960).

Mann, D. B., Stewart, R. B., Thermodynamic properties of helium at low temperatures and high pressures, Trans. Am. Soc. Mech. Engrs. J. Heat Transfer **81**, No. 4, 323–326 (Nov. 1959).

Mann, D. E., Some aspects of fluorine flame spectroscopy, Proc. Propellant Thermodynamics and Handling Conf. Spec. Rept. 12 (Ohio State University, Columbus, Ohio, June 1960).

Mann, D. E., Thrush, B. A., On the absorption spectrum of CF_3 and its vibrational analysis, J. Chem. Phys. **33**, No. 6, 1732–1734 (Dec. 1960).

Mann, D. E., Thrush, B. A., Lide, D. R., Ball, J. J., Acquista, N., Spectroscopy of fluorine flames. I. Hydrogen-fluorine flame and the vibration-rotation emission spectrum of HF, J. Chem. Phys. **34**, No. 2, 420–431 (Feb. 1961).

Mann, W. B., Recent work with compensated internal gas counters for the standardization of gaseous radionuclides, Proc. Symp. Metrology of Radionuclides, IAEA (Vienna, Austria), p. 307 (1960).

Mann, W. B., Routine methods of radioactivity standardization at the National Bureau of Standards (USA), Proc. Symp. Metrology of Radionuclides, IAEA (Vienna, Austria), p. 89 (1960).

Mann, W. B., Seliger, H. H., Radioactivity standardization in the United States, 2d United Nations Geneva Conf. (1960).

Mann, W. B., Seliger, H. H., Marlow, W. F., Medlock, R. W., Recalibration of the NBS carbon-14 standard by Geiger-Müller and proportional gas counting, Rev. Sci. Instr. **31**, No. 7, 690 (1960).

Marcus, M., Newman, M., The permanent function as an inner product, Bull. Am. Math. Soc. **67**, 223–224 (1961).

Margoshes, M., Some properties of new or modified excitation sources, Symp. Spectroscopic Excitation, Am. Soc. Testing Materials Spec. Tech. Publ. **259**, 46–58 (1960).

Marimont, R. B., Applications of graphs and Boolean matrices to computer programming, SIAM Review **2**, No. 4, 259–268 (Oct. 1960).

Martin, W. C., Tech, J. L., Energy levels and magnetic dipole transitions in the $4p^4$ ground configuration of singly ionized atomic bromine (Br II), J. Opt. Soc. Am. **51**, No. 6, 591–594 (June 1961).
Marton, L., Note historique sur les premières années de la microscopie électronique, Extrait Bull. Acad. Roy Belg. (Classe des Sciences) **5**, 119–121 (Mar. 1959).
Maryott, A., Birnbaum, G., Non-resonant microwave absorption and relaxation frequency at elevated pressures, J. Phys. Chem. **64**, No. 11, 1778–1780 (Nov. 1960).
Marzullo, S., Bunting, E. N., Some ceramic dielectrics with a very low temperature coefficient of capacitance, J. Am. Ceram. Soc. **43**, No. 11, 609 (Nov. 1960).
Mathey, R. G., Watstein, D., Investigation of bond in beam and pullout specimens with high-yield-strength deformed bars, J. Am. Concrete Inst. **32**, No. 9, 1071–1090 (Mar. 1961).
Matsushita, S., Seasonal and day-to-day changes of the central positions of the S_q overhead current system, J. Geophys. Research **65**, No. 11, 3835–3839 (Nov. 1960).
Meggers, W. F., Tech, J. L., The centennial of spectroscopy, J. Opt. Soc. Am. **50**, No. 11, 1035–1038 (Nov. 1960).
Megill, L. R., Jamnick, P. M., Cruz, J. E., Seasonal variations in the twilight enhancement of [OI] 5577, J. Atmospheric and Terrest. Phys. **18**, 309–314 (Aug. 1960).
Meijer, P. H. E., Line shape of ultraviolet absorption in solid noble gases, J. Chem. Phys. **34**, 2078–2082 (1961).
Meissner, P., Cunningham, J. A., Kettering, C., Computer for weather data acquisition, Proc. Eastern Joint Computer Conf. **18**, No. 2.1, 57–66 (Dec. 1960).
Mendlowitz, H., Optical transmissivity and characteristic energy losses, J. Opt. Soc. Am. **50**, No. 7, 739–740 (July 1960).
Meyerson, M. R., Lithium, Am. Soc. Metals Handb. **1**, 1213 (1961).
Meyerson, M. R., Ney, W. R., Young, T. R., The development of more stable gage blocks, Materials Research and Standards (ASTM Bull.), **1**, No. 5, 368–374 (May 1961).
Meyerson, M. R., Rosenberg, S. J., Definitions relating to metals and metalworking, Am. Soc. Metals Handb. **1**, 1–41 (1961).
Michaelis, R. E., Spectroscopic standard samples of titanium and high-temperature alloys, Appl. Spectroscopy **15**, 7 (1961).
Michaelis, R. E., Standard samples and related materials for spectrochemical analysis, Am. Soc. Testing Materials Spec. Tech. Publ. **58–D**, 116 (1960).
Mielenz, K. D., Simple calculus for all-dielectric interference filters of the Fabry-Perot Type, J. Opt. Soc. Am. **50**, No. 10, 1014 (Oct. 1960).
Misme, P., Bean, B. R., Thayer, G. D., Models of the atmospheric radio refractive index, Proc. IRE **48**, No. 8, 1498–1501 (Aug. 1960).
Mockler, R. C., Barnes, J. A., Maser frequency stability, Proc. 13th Annual Frequency Control Symp., p. 583–595 (May 12–14, 1959).
Mockler, R. C., Beehler, R. E., NBS atomic frequency standards, Proc. 14th Annual Symp. Frequency Control, Atlantic City, N.J. (May 31–June 3, 1960), p. 298–309 (Signal Corps Eng. Laboratories, Ft. Monmouth, N.J., 1961).
Mockler, R. C., Beehler, R. E., Snider, C. S., Atomic beam frequency standards, IRE Trans. Instrumentation **I–9**, No. 2, 120–132 (Sept. 1960).
Montgomery, G. F., Improving rectifier circuits, Electronics **34**, No. 14, 88 (Apr. 7, 1961).
Moore, D. G., Studies on the flame-spraying of aluminum oxide, Metal Finishing J. **6**, No. 70, 397 (Oct. 1960).
Moore, G. A., Shives, T. R., Properties of iron and iron alloys (high purity irons (99.9+% Fe)), Am. Soc. Metals Handb. **1**, 1206 (1961).
Moore, T. R., A screening method for large informational retrieval systems, Proc. Joint IRE–AIEE–ACM Computer Conf. **6.3**, 259–274 (1961).
Mordfin, L., Analytical study of creep deflection of structural beams, NASA Tech. Note **D–661** (Dec. 1960).
Mordfin, L., Halsey, N., Experimental investigation of creep deflection of extruded and riveted I-beams, NASA Tech. Note **D–662** (Dec. 1960).
Morrow, W. L., Determination of wax in paper, TAPPI **44**, No. 2, 120 (1961).
Mosburg, E. R., Murphey, W. M., A recalibration of the NBS standard thermal neutron flux, Reactor Sci. and Tech. J. Nuclear Eng. **14**, Pt. A.B., 25–30 (1961).
Moss, M. L., Posner, A. S., X-ray diffraction study of a cellular teleost bone, Nature **188**, 1037 (Dec. 1960).
Murad, E., The photolysis of ethyl vinyl ether, J. Am. Chem. Soc. **83**, 1327–1330 (1961).
Nettleton, R. E., Casimir coefficients and minimum entropy production, J. Chem. Phys. **33**, No. 1, 237–241 (July 1960).
Nettleton, R. E., Density fluctuation and heat conduction in a pure liquid, Phys. of Fluids **4**, No. 1, 74 (Jan. 1961).
Newman, E. S., Berman, H. A., Letter to Editor of Revue des Materiaux (first), Revue des Materiaux **C**, No. 540, 231 (Sept. 1960).

Newman, M., Irrational power series, Proc. Am. Math. Soc. **11,** 699–702 (Oct. 1960).
Newman, M., Periodicity modulo m and divisibility properties of the partition function, Trans. Am. Math. Soc. **97,** 225–236 (1960).
Newman, M., Subgroups of the modular group and sums of squares, Am. J. Math. **82,** No. 4, 761–778 (Oct. 1960).
Nicholls, R. W., The Franck-Condon factor ($q_{v'v''}$) array to high vibrational quantum numbers for the $O_2(B^3\Sigma_u^- - X^3\Sigma_g^+)$ Schumann-Runge band system, Can. J. Phys. **38,** 1705–1711 (1960).
Nicholls, R. W., On the nature of the ultraviolet light which accompanies the decomposition of some azides, J. Phys. Chem. **64,** 1760 (1960).
Nicholls, R. W., Krishnamachari, S. L. N. G., On the emission spectrum of NCO excited in condensed discharged N_2+CO at 4.2° K, Can. J. Chem. **38,** 1652 (1960).
Norton, K. A., Carrier-frequency dependence of the basic transmission loss in tropospheric forward scatter propagation, J. Geophys. Research **65,** 2029–2045 (July 1960).
Norton, K. A., Low and medium frequency radio propagation, Electromagnetic Wave Prop. Proc. Intern. Conf. Propagation of Radio Waves, Liege, Belgium, 1958, p. 375 (Academic Press, Inc., New York, N.Y., 1960).
O'Brien, B. J., Van Allen, J. A., Roach, F. E., Gartlein, C. W., Correlation of an auroral arc and a subvisible monochromatic 6300 A arc with outer-zone radiation on November 28, 1959, J. Geophys. Research **65,** No. 9, 2759–2766 (Sept. 1960).
O'Brien, B. J., Van Allen, J. A., Roach, F. E., Gartlein, C. W., Correlation of visual and subvisual auroras with changes in the outer Van Allen radiation zone, IBY Bull. No. 45, 1–16 (Mar. 1961).
Ogburn, F., Roberts, W. H., The nature, cause, and effect of porosity in electrodeposits. VI. Note on a magnetic method of detecting corrosion currents, Plating **48,** No. 2, 168–169 (Feb. 1961).
Okabe, H., McNesby, J. R., Vacuum ultraviolet photolysis of ethane: molecular detachment of hydrogen, J. Chem. Phys. **34,** 2, 668–669 (Feb. 1961).
Olesen, J. K., Wright, J. W., The relationships of low-height ionosonde echoes to auroral-zone absorption and VHF forward scatter, J. Geophys. Research **66,** No. 4, 1127–1134 (Apr. 1961).
Ondik, H. M., MacGillairy, C. H., Block, S., The structure of the monoclinic form of sodium tetrametaphosphate tetrahydrate, Acta Crystallographica **14,** 555 (1961).
Ormsby, W. C., The role of surface tensions in determining certain clay-water properties, Bull. Am. Ceram. Soc. **39,** No. 8, 408–412 (Aug. 1960).
Ostrowski, A. M., A. quantitative formulation of Sylvester's law of inertia, Natl. Acad. Sci. Proc. **45,** No. 5, 740–744 (May 1959).
Ostrowski, A. M., On the bounds of a one-parametric family of matrices, J. Reine Agnew. Math. **200,** 190–199 (1958).
Ostrowski, A. M., On the convergence of the Rayleigh quotient iteration for the computation of the characteristic roots and vectors, II, Arch. Rational Mech. Analysis **2,** 423–428 (1959).
Ostrowski, A. M., Un nouveau critere d'univalence des transformations dans un R^n, Compt. Rend. Acad. Sci. (Paris, France), **248,** 348–350 (1959).
Paffenbarger, G. C., Denton, G. B., Teeth, artificial Encyclopaedia Britannica **21,** 878 (Jan. 1960).
Parker, R. A., Wasilik, J. H., Dielectric constant and dielectric loss of TiO_2 (Rutile) at low frequencies, Phys. Rev. **120,** No. 5, 1631–1637 (Dec. 1960).
Payne, L. E., Pell, W. H., The Stokes flow about a spindle. Quart. Appl. Math. **18,** 257–262 (1960).
Pearl, M., A further extension of Cayley's parameterization, Can. J. Math. **11,** No. 1, 48–50 (1959).
Pearl, M., On normal and EPr matrices, Mich. J. Math. **6,** No. 1, 1–5 (1939).
Peavy, B. A., Available heat sinks for protected underground installations, Proc. Meeting Environmental Engineering in Protective Shelters, Feb. 8–10, 1960, Natl. Acad. Sci.-Natl. Research Council, p. 69–118 (1961).
Pell, W. H., Payne, L. E., On Stokes flow about a torus, Mathematika **7,** 78–92 (1960).
Penner, S., Calculations of properties of magnetic deflection systems, Rev. Sci. Instr. **32,** No. 2, 150–160 (Feb. 1961).
Perloff, A., Posner, A. S., Crystalline basic calcium orthophosphate (hydroxyapatite), Book, Inorganic Syntheses, **VI,** Ch. II, A–6 (McGraw-Hill Co., Inc., New York, N.Y., 1960).
Phillips, C. W., Goddard, W. F., Jr., Achenbach, P. R., A rating method for refrigerated trailer bodies hauling perishable foods, ASHRAE J. **2,** No. 5, 45–50 (May 1960).
Phillips, C. W., Goddard, W. F., Achenbach, P. R., Johnson, H. D., Penney, R. W., A rating method for refrigerated trailer bodies hauling perishable food, U.S. Dept. Agric. Marketing Research Rept. No. 433 (Sept. 1960).

Peiperl, M. D., Carpenter, F. G., Deitz, F. R., The automatic chloride titrator in the analysis of some ionic constituents, Proc. 6th Tech. Session on Bone Char 1959, p. 53 (Bone Char Research Project Inc., Charlestown, Mass., 1961).
Pike, R. G., Hubbard, D., Newman, E. S., Binary silicate glasses in the study of alkali-aggregate reaction, Highway Research Board Bull. **275,** 39–44 (1960).
Plitt, K. F., Dunlap, L. A., A burst test for high strength fabrics, ASTM Bull. **246,** 33 (1960).
Plumb, H. H., Edlow, M. H., Cataland, G., The reproducibility of carbon resistance and helium vapor pressure measurements, Proc. Xth Intern. Congress of Refrigeration, Copenhagen, Denmark, 1959, Book, Progress in Refrigeration in Science and Technology **I,** 184–187 (Pergamon Press, Inc., London, England, 1960).
Plyler, E. K., Tidwell, E. D., The rotational constants of hydrogen chloride, Z. Elektrochemie **64,** No. 5, 717–720 (Feb. 1960).
Plyler, E. K., Tidwell, E. D., Benedict, W. S., Vibration-rotation bands of N_2O, J. Opt. Soc. Am. **50,** No. 12, 1243–1263 (Dec. 1960).
Posner, A. S., Stutman, J. M., Lippincott, E. R., Hydrogen bonding in calcium-deficient hydroxyapatites, Nature **188,** No. 4749, 486–487 (Nov. 1960).
Pottasch, S. R., The extent of H II regions, Astrophys. J. Note **132,** No. 1, 269–271 (July 1960).
Pottasch, S. R., Thomas, R. N., Thermodynamic structure of the outer solar atmosphere. VI. Effect of departures from the Saha equation on infrared properties of the low chromosphere, Astrophys. J. **132,** No. 1, 195–201 (July 1960).
Powell, R. C., Rasmussen, A. L., A radio-frequency permittimeter, IRE Trans. Instrumentation **I–9,** No. 2, 179–184 (Sept. 1960).
Powell, R. L., Bunch, M. D., Caywood, L. P., Low-temperature thermocouple thermometry, Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **6,** Paper H–6, 537–541 (Plenum Press, Inc., New York, N.Y., 1961).
Powell, R. L., Bunch, M. D., Corruccini, R. J., Low-temperature thermocouples. I. Gold-cobalt or constantan vs. copper or "normal" silver, Cryogenics **1,** 139–150 (Mar. 1961).
Powell, R. L., Bunch, M. D., Gibson, E. F., Low-temperature transport properties of commercial metals and alloys. III. Gold-cobalt, J. Appl. Phys. **3,** 504 (Mar. 1960).
Powell, R. L., Harden, J. L., Gibson, E. F, Low-temperature transport properties of commercial metals and alloys. IV. Reactor grade Be, Mo, and W, J. Appl. Phys. **31,** No. 7, 1221–1224 (July 1960).
Pruitt, J. S., Pohlit, W., Vergleichmessungen mit intensitatsstandards für energiersiche bremsstrahlung (Comparison measurements of intensity standards for high energy bremsstrahlung), Z. Naturforschung **15b,** No. 9, 617–619 (1960).
Pummer, W. J., Wall, L. A., Preparation and properties of aromatic fluorocarbons, J. Chem. Eng. Data **6,** No. 1, 76–78 (Jan. 1961).
Purcell, J. R., Payne, R. G., Superconducting rectifiers, Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **6,** Paper C–2, 149–153 (Plenum Press, Inc., New York, N.Y., 1961).
Purcell, J. R., Schmidt, A. F., Jacobs, R. B., The Venturi tube as a liquefied-gas flow measuring device, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5,** Paper F–2, 282–288 (Plenum Press, Inc., New York, N.Y., 1960).
Radford, H. E., Microwave Zeeman effect of free hydroxyl radicals, Phys. Rev. **122,** 114 (1961).
Radford, H. E., Rice, F. O., Green and purple sulfur: electron spin resonance studies, J. Chem. Phys. **33,** No. 3, 774–776 (Sept. 1960).
Raybold, R. L., Electroless plated contacts to silicon carbide, Rev. Sci. Instr. **31,** No. 7, 781–782 (July 1960).
Reed, R. P., Mikesell, R. P., Greson, R. L., Some mechanical properties of magnesium alloys at low temperatures, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5,** Paper H–3, 397–405 (Plenum Press, Inc., New York, N.Y., 1960); Symp. Low-Temperature Properties of High-Strength Aircraft and Missile Materials, Philadelphia, Pa., Am. Soc. Testing Materials Spec. Tech. Publ. **287,** 61–73 (1960).
Reid, W. E., The mechanism of electrolytic deposition of titanium from fused salt media, J. Electrochem. Soc. **108,** No. 4, 393–394 (Apr. 1961).
Reinhart, F. M., Twenty-year atmospheric corrosion investigation of zinc-coated and uncoated wire and wire products, Am. Soc. Testing Materials Spec. Tech. Publ. **290,** 1–141 (June 1961).
Reinhart, F. W., Standards development by ASTM committee D–20 on plastics, SPE J. **16,** 800 (Aug. 1960).
Reinhart, F. W., Standards for plastic pipe and fittings, SPE J. **17,** 160 (Feb. 1961).
Reinhart, F. W., Standards for plastics—who establishes standards? SPE J. **16,** 175 (Feb. 1960).

Reinboldt, W. C., Menard, J. P., Mechanized conversion of colorimetric data to Munsell renotations, J. Opt. Soc. Am. **50,** No. 8, 802–807 (Aug. 1960).
Rice, J. R., Tchebychev approximation by ab^x+c, J. Soc. Ind. Appl. Math. **8,** No. 4, 691–702 (1960).
Richards, R. J., Steward, W. G., Jacobs, R. B., Transfer of liquid hydrogen through uninsulated lines, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5,** Paper B–4, 104–110 (Plenum Press, Inc., New York, N.Y., 1960).
Richardson, A. C. B., Low scatter high current gas target for D–D neutrons, Rev. Sci. Instr. **31,** No. 11, 1202–1203 (Nov. 1960).
Richardson, J. M., Microwave spectroscopy—atomic frequency standards, Book Encyclopedia of Spectroscopy, p. 647–656 (Reinhold Publ. Corp., New York, N.Y., 1960).
Richmond, J. C., Harrison, W. N., Equipment and procedure for the evaluation of total hemispherical emittance, Bull. Am. Ceram. Soc. **39,** No. 11, 668 (Nov. 1960).
Roach, F. E., Variations of [OI] 5577 A emission in the upper atmosphere, Ann. Geophys. **17,** 172–180 (Apr.–June 1961).
Roach, F. E., Megill, L. R., Integrated starlight over the sky, Astrophys. J. **133,** No. 1, 228–242 (Jan. 1961).
Roach, F. E., Moore, J. G., Bruner, E. C., Jr., Cronin, H., Silverman, S. M., The height of maximum luminosity in an auroral arc, J. Geophys. Research **65,** No. 11, 3575–3580 (Nov. 1960).
Robbins, C. R., The compound $BaTiGe_3O_9$, J. Am. Ceram. Soc. **43,** No. 11, 610 (Nov. 1960).
Robinson, R. A., Bower, V. E., The ionization constant of hydroxylamine, J. Phys. Chem. **65,** 1279–1280 (1961).
Rootare, H. M., Deitz, V. R., Carpenter, F. G., Solubility product phenomena in hydroxyapatite—water systems, Proc. 6th Tech. Session on Bone Char 1959, p. 287 (Bone Char Research Project Inc., Charlestown, Mass., 1961).
Rosberry, F. W., Measurement of contrast in the aerial image, Photogrammetric Eng. **27,** 155–159 (Mar. 1961).
Rosenberg, S. J., A centry-old razor, Progress, p. 94–96 (1961).
Rosenberg, S. J., Royston, T. P., A stainless steel for standard weights, Materials Research and Standards (ASTM Bull.), **1,** No. 1, 21 (Jan. 1961).
Rosenblatt, J. R., On prediction of system behavior, IRE Trans. Reliability and Quality Control **RQC–9,** 23–28 (June 1960).
Rosenblatt, J. R., Statistical models for component aging experiments, Intern. Conv. Record, IRE **8,** Pt. 6, 115–124 (1960).
Rosenstock, H. M., On the classical approximation in the statistical theory of mass spectra, J. Chem. Phys. **34,** 2182–2183 (June 1961).
Roth, R. S., Phase equilibria in the system cadmium oxide-niobium oxide, J. Am. Ceram. Soc. **44,** No. 1, 49–50 (Jan. 1961).
Rubin, R. J., Statistical dynamics of simple cubic lattices. Model for the study of Brownian motion, J. Math. Phys. **1,** 309 (1960).
Rubin, R. J., Statistical dynamics of simple cubic lattices. Model for the study of Brownian motion, Pt. II, J. Math. Phys. **2,** 373 (1961).
Rubin, R. J., Shuler, K. E., On the dissociation of polyatomic molecules, J. Chem. Phys. **33,** 438 (1960).
Ruehrwein, R. A., Hashman, J. S., Edwards, J. W., Chemical reactions of free radicals at low temperature, J. Phys. Chem. **64,** 1317–1322 (1960).
Rundle, H. N., Ionization of a static interplanetary gas and expected emission lines from this gas, Planet and Space Sci. **2,** 86–98 (1960).
Rundle, H. N., On the night sky emission spectra between 5000 Å and 6500 Å, Astrophys. J. **131,** 15–24 (Jan.–May 1960).
Rundle, H. N., Twilight spectra near the equator, Ann. Geophys. **16,** No. 1, 152–153 (Mar. 1960).
Saito, S., Bretemps, F. R., WWV time signal receiver, Electronic Ind. **19,** No. 8, 214–216 (Aug. 1960).
Schafer, G. E., A modulated subcarrier technique of measuring microwave phase shifts, IRE Trans. Instrumentation **I–9,** No. 2, 217–219 (Sept. 1960).
Schafer, G. E., Mismatch errors in microwave phase shift measurements, IRE Trans. Microwave Theory and Tech. **MTT–8,** No. 6, 617–622 (Nov. 1960).
Scheer, M. D., Klein, R., The activation energy for hydrogen atom addition to propylene, J. Phys. Chem. **65,** 375–377 (1961).
Scheiber, D. J., An ultra-low frequency bridge for dielectric measurements, 1960 Annual Report, Conf. Electrical Insulation, Natl. Acad. Sci.-Natl. Research Council, p. 1–10 (1961).
Schiff, H. I., Sugden, T. M., Some atomic reactions by absorption spectroscopy, Nature **185,** 759 (1960).

Schmidt, A. F., Purcell, J. R., Wilson, W. A., Smith, R. V., An experimental study concerning the pressurization and stratification of liquid hydrogen, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5**, Paper J–6, 487–497 (Plenum Press, Inc., New York, N.Y., 1960); Revised version J. Research NBS **65C** (Eng. and Instr.), No. 2, 81–87 (Apr.–June 1961).

Schmidt, V. A., Edelman, S., Smith, E. R., Jones, E., Optical calibration of vibration pickups at small amplitudes, J. Acoust. Soc. Am. **33**, No. 6, 748–751 (June 1961).

Schneider, S. J., The mechanical properties of ceramics and their measurement at elevated temperatures, Book, Thermoelectricity Chapt. 21, 342–357 (John Wiley and Sons, Inc., New York, N.Y., 1960).

Schnepp, O., The absorption spectra of magnesium and manganese atoms in solid rare gas matrices, J. Phys. Chem. Solids **17**, 188–195 (1961).

Schnepp, O., Dressler, K., Absorption spectra of solid xenon, krypton, and argon in the vacuum ultraviolet, J. Chem. Phys. **33**, 49–55 (1960).

Schoen, L. J., Broida, H. P., Effect of structure of the spectra emitted by solid nitrogen during electron bombardment, J. Mol. Spectroscopy **5**, No. 5, 416–419 (Nov. 1960).

Schrack, R. A., Penner, S., Leiss, J. E., Low-energy photoproduction of neutral mesons from complex nuclei, Il Nuovo Cimento **16**, No. X, 759–761 (Mar. 1960).

Schweitzer, W. G., Hyperfine structure and isotope shifts in the 2537A line of mercury, J. Opt. Soc. Am. **51**, No. 6, 692–693 (June 1961).

Scott, A. H., Harris, W. P., Residual losses in a guard-ring micrometer-electrode holder for solid-disk dielectric specimens, 1960 Annual Report, Conf. Electrical Insulation, Natl. Acad. Sci.-Natl. Research Council, p. 11–17 (1961).

Senftle, F. E., Pankey, T., Grant, F. A., Magnetic susceptibility of tetragonal titanium dioxide, Phys. Rev. **120**, No. 3, 820–825 (Nov. 1, 1960).

Severo, N. C., Zelen, M., Normal approximation to the chi-square and non-central F probability functions, Biometrika **47**, No. 3–4, 411–416 (1960).

Shapley, A. H., International geophysical calendar for 1961, J. Radio Research Laboratories (Japan) **7**, No. 33, 545–548 (Sept. 1960); Natl. Acad. Sci.-Natl. Research Council IGY Bull. No. 42, 6–10 (Dec. 1960); Trans. AGU **41**, No. 4, 722–726 (Dec. 1960); IUGG Chronicle No. 33, 272–275 (Dec. 1960); CIG News No. **3**, 80–83 (Dec. 1960); Science **132**, No. 3444, 1941–1943 (Dec. 30, 1960); J. Geophys. Research **66**, No. 1, 336–339 (Jan. 1961); Nature No. 4758, 9–11 (Jan. 7, 1961); World Meteorological Organization Bull. **X**, No. 1, 47–50 (Jan. 1961); J. Atmospheric and Terrest. Phys. **20**, No. 1, 72–76 (Feb. 1961).

Shapley, A. H., Upper atmosphere, Sect. 3, Science in Antarctica Part II, Natl. Acad. Sci.-Natl. Research Council Publ. **878** (1961).

Shapley, A. H., Villard, O. G., Jr., Satellites and the Upper Atmosphere Book, Science in Space Chapt. 8, p. 169–181 (McGraw-Hill Book Co., Inc., New York, N.Y., 1961).

Shepley, L. C., Bestul, A. B., Variations of surface tension calculated with improved approximation for activity coefficient, J. Am. Ceram, Soc. **43**, No. 7, 386–387 (July 1960).

Sherfey, J. M., Titanium (III) chloride and titanium (III) bromide (titanium trichloride and titanium tribromide), Book, Inorganic Synthesis by E. S. Rochow, Chapt. IV–B, Sect. 17, p. 57–61 (McGraw-Hill Book Co., Inc., New York, N.Y., 1960).

Shields, W. R., Craig, D. N., Dibeler, V. H., Absolute isotopic abundance ratio and atomic weight of silver, J. Am. Chem. Soc. **82**, 5033–5036 (1960).

Shields, W. R., Craig, D. N., Dibeler, V. H., Absolute mass spectrometric determination of the atomic weight of silver, Proc. Intern. Conf. Nuclidic Masses, Ed. H. E. Duckworth, p. 519–531 (University of Toronto Press, Toronto, Ontario, Canada, 1960).

Shiffman, C. A., The intermediate state structure and surface energy of mercury, Proc. VIIth Intern. Conf. Low Temperature Physics, p. 208–210 (University of Toronto, Canada, 1960).

Shumaker, J. B., Jr., Arc source for high temperature gas studies, Rev. Sci. Instr. **32**, No. 1, 65–67 (Jan. 1961).

Siddiqui, M. M., Tests for regression coefficient when errors are correlated, Ann. Math. Stat. **31**, No. 4, 929–938 (Dec. 1960).

Skramstad, H. K., Urban, W. D., Combined analog-digital differential analyzer, Proc. Combined Analog-Digital Computer Systems Symp. p. 1–7 (Dec. 1960).

Skramstad, H. K., Urban, W. D., Hahn, W. R., Combined analog-digital differential analyzer, Electronic Design **8**, No. 17, 8–11 (Aug. 17, 1960).

Smith, D. K., A simple low temperature specimen holder for the Norelco X-ray diffractometer, Norelco Reporter **111**, No. 1, 11 (Jan.–Feb. 1961).

Smith, E. K., The morphology of sporadic E, Proc. XIIIth General Assembly URSI (London, England, 1960), Natl. Acad.-Sci.-Natl. Research Council Publ. **880**, 218 (1961).

Smith, E. K., Finney, J. W., Peculiarities of the ionosphere in the Far East; Sporadic E and F region scatter, Proc. URSI–AGI Symp. (Brussels, Belgium, 1959), Book, Some Ionospheric Results Obtained During IGY, Ed. W. J. G. Beynon, p. 182 (Elsevier Publ. Co., Princeton, N.J., 1960).
Smith, J. C., Blandford, J. M., Schiefer, H. F., Stress-strain relationships in yarns subjected to rapid impact loading: 6. Velocities of strain waves resulting from impact, Textile Research J. **30,** No. 10, 752–760 (Oct. 1960).
Smith, K. D., A simple low-temperature specimen holder for an X-ray diffractometer, Norelco Reporter **VII,** No. 1, 11–12 (Jan.–Feb. 1961).
Smith, S. J., Branscomb, L. M., Optical methods for negative ion studies, Rev. Sci. Instr. **31,** No. 7, 733–747 (July 1960).
Spangenberg, W. G., Rowland, W. R., Convective circulation in water induced by evaporative cooling Phys. of Fluids **4,** No. 6, 743–750 (June 1961).
Spangenberg, W. G., Rowland, W. R., Optical study of boundary-layer transition proccesses in a supersonic air stream, Phys. of Fluids **3,** No. 5, 667–684 (Sept.–Oct. 1960).
Spencer, L. V., Future needs in shielding research and theory, Proc. NRDL–OCDM Shielding Symp., San Francisco, Calif. (Oct. 31–Nov. 1, 1960).
Spiegel, V., Jr., Richardson, A. C. B., Age to indium resonance for D–D neutrons in heavy water, Nuclear Sci. and Eng. **10,** No. 1, 11–15 (1961).
Spinner, S., Cleek, G. W., Temperature dependance of Young's modulus of vitreous germania and silica, J. Appl. Phys. **31,** No. 8, 1407–1410 (1960).
Stanford, J. W., Weigel, K., Paffenbarger, G. C., Second revision of American Dental Association Specification No. 4 for dental inlay casting wax, J. Am. Dental Assoc. **62,** 45 (Jan. 1961).
Stansbury, C., A general description of D–C digital voltmeters, Am. Inst. Elec. Engrs. Trans. Paper No. 61–721 (Apr. 1961).
Stavroudis, O. N., Sutton, L. E., Rapid method for interpolating refractive index measurements, J. Opt. Soc. Am. **51,** No. 3, 368–370 (Mar. 1961)
Stegun, I., Abramowitz, M., Generation of Bessel functions on high speed computers, Math. Tables and Other Aids to Computation **11,** 255–257 (1957).
Stephens, R. E., Four-color achromats and superchromats, J. Opt. Soc. Am. **50,** No. 10, 1016–1019 (Oct. 1960).
Stewart, R. B., Johnson, V. J., A compilation and correlation of the P–V–T data of normal hydrogen from saturated liquid to 80 °K, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5,** Paper K–7, 557–565 (Plenum Press, Inc., New York, N.Y., 1960).
Stief, L., Ausloos, P., Vapor-phase gamma-radiolysis of azomethane, J. Phys. Chem. **65,** 877–881 (1961).
Stern, K. H., Buplin, M., Mechanism of the isothermal decomposition of potassium perchlorate, J. Phys. Chem. **64,** 1781 (1960).
Stern, K. H., Richardson, E. A., The ion pair-quadrupole equilibrium. Tetrabutylammonium bromide in methanol-benzene mixtures, J. Phys. Chem. **64,** 1901 (1960).
Stober, A. K., A method for efficiently providing low temperature liquids on a large scale to an accelerated experimental program. Proc. Xth Intern. Congress of Refrigeration (Copenhagen, Denmark, 1959). Book, Progress in Refrigeration in Science and Technology **I,** No. 1, 17–18 (Pergamon Press, Inc., London, England, 1960).
Stromberg, R. R., The interfacial properties of polyesters at glass and water surfaces, Soc. Plastic Engr. **15,** 882–886 (Oct. 1959).
Stromberg, R. R., Kline, G. M., Adsorption of polyesters and other polymers to glass and other substrates, Poliplasti **9,** 15 (Jan.–Feb. 1961); Modern Plastics **38,** 123 (Apr. 1961); Modern Plastics **38,** 241 (May 1961).
Sweeney, W. T., Forty years of dental research at the National Bureau of Standards, Capital Chemist, **10,** 228 (Oct. 1960).
Swindells, J. R., Liquid-in-glass thermometers, Inst. and Control Systems **34,** 846 (1961).
Switzer, G., Swanson, H. E., Paratellurite, a new mineral from Mexico, Am. Mineralogist **45,** 1272 (Nov.–Dec. 1960).
Tate, D. R., The NBS absolute gravity experiment, Proc. 2d AFCRC Military Geodesy Seminar, GRD Research Notes No. 40 (Jan. 12–14, 1960).
Taylor, J. K., Educational activities of Washington scientists, J. Wash. Acad. Sci. **50,** No. 6, 5 (1960).
Taylor, J. K., Knipling, P., Smith, F., Project ideas for young scientists, Joint Board on Sci. Ed., p. 144 (1960).
Taylor, J. K., Young, J. A., Chemistry teaching conference in the Washington area, J. Chem. Ed. **37,** 478 (1960).
Taylor, L. S., Physical quantities proposed for radiation measurements, Proc. 9th Intern. Congress of Radiology, July 23–30, 1959 (Munchen, Germany), p. 1301–1302 (1960).

Taylor, L. S., Radiation protection standards, Roentgen Bl. **8**, No. 2, 33–46 (Feb. 1960); Radiology **74**, 824–831 (May 1960).
Taylor, W. L., VLF attenuation for east-west and west-east daytime propagation using atmospherics, J. Geophys. Research **65**, No. 7, 1933–1938 (July 1960).
Tchen, C. M., Diffusion of particles in turbulent flow, Book, Advances in Geophys. 6: Atmospheric Diffusion and Air Pollution, p. 165–173 (Academic Press, Inc., New York and London, England, 1959).
Teele, R. P., International standard of light, J. Opt. Soc. Am. **50**, 1135 (Nov. 1960).
Temkin, A., Lamkin, J. C., Application of the method of polarized orbitals to the scattering of electrons from hydrogen, Phys. Rev. **121**, No. 3, 788–794 (Feb. 1, 1961).
Thomas, R. N., Effect of departures from local thermodynamic equilibrium on inferences of stellar atmospheric temperatures, Book, Optical Spectrometric Measurements of High Temperatures, Ed. P. J. Dickerman, p. 14–26 (University of Chicago Press, Chicago. Ill., 1961).
Thomas, R. N., Zirker, J. B., Departure from the Saha equation for ionized helium: II. Atmospheric thickness too small to satisfy detailed balance in the resonance lines, Astrophys. J. **133**, No. 2, 588–595 (Mar. 1961).
Thompson, M. C., Jr., Janes, H. B., Kirkpatrick, J., An analysis of time variations in tropospheric refractive index and apparent radio path length, Geophys. Research **65**, 193 (Jan. 1960).
Tilton, L. W., Taylor, J. K., Refractive index measurements, Book, Physical Methods in Chemical Analysis, 2d Revised Ed. **II**, 412–461 (Academic Press, Inc., New York, N.Y., 1961).
Tipson, R. S., Nomenclature of carbohydrates, J. Chem. Documentation **2**, No. 3, 3–7 (1961).
Trees, R. E., Low even configurations in the first spectrum of thorium, Physica **26**, 353–360 (1960).
Truesdell, C., Modern theories of materials, Trans. Soc. Rheology **IV**, 9–22 (1960).
Truesdell, C., Zu den Grundlagen der mechanik und thermodynamik, Physik, Bl. **16**, No. 10, 512–517 (1960).
Truesdell, C., Kanwal, R. P., Electric current and fluid spin created by the passage of a magnetosonic wave, Archiv. for Radional Mech. and Analysis **5**, No. 5, 432–439 (1960).
Truesdell, C., Toupin, R., The classical field theories, Handbuch der Physik **III**, No. 1, 226–793 (Springer-Verlag. Berlin, Germany, 1960).
Tveten, L. H., Long-distance one-hop F1 propagation through the auroral zone, J. Geophys. Research Letter to Editor **66**, No. 6. 1683–1684 (June 1961).
Vacher, H. C., Burnett, H. E., Duff, R. H., Vacuum chamber for the deposition of carbon and shadow casting of metals (abstract), J. Appl. Phys. **31**, 1836 (Oct. 1960).
Van Gundy, D. A., Mullen, L. O., Jacobs, R. B., A study of condensing-vacuum insulation, Proc. 1959 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **5**, Paper C–5, 162–170 (Plenum Press, Inc., New York, N.Y., 1960).
Van Valkenburg, A., Synthetic mica, Book, Encyclopedia of Chemistry Technology, p. 480 (Interscience Encyclopedia, Inc., New York, N.Y., 1960).
VanZandt, T. E., Bowles, K. L., Use of the incoherent scatter technique to obtain ionospheric temperatures, J. Geophys. Research **65**, No. 9, 2627–2628 (Sept. 1960).
VanZandt, T. E., Norton, R. B., Stonehocker, G. H., Photochemical rates in the equatorial F2 region from the 1958 eclipse, J. Geophys. Research **65**, No. 9, 2003–2009 (July 1960); Proc. URSI–AGI Symp. (Brussels, Belgium, 1959), Book, Some Ionospheric Results Obtained During IGY, Ed. W. J. G. Beynon, p. 43 (Elsevier Publ. Co., Princeton, N.J., 1960).
Wachtman, J. B., Tefft, W. E., Lam, D. G., Jr., Epstein, W. S., Exponential temperature dependence of Young's modulus for several oxides, Phys. Rev. **122**, 1754 (June 1961).
Wait, J. R., A comparison between theoretical and experimental data on phase velocity of VLF radio waves, Proc. IRE **49**, No. 6, 1089–1090 (June 1961).
Wait, J. R., A conference on the propagation of ELF electromagnetic waves, Proc. IRE **48**, No. 9, 1648–1649 (Sept. 1960).
Wait, J. R., A diffraction theory for LF sky-wave propagation, J. Geophys. Research **66**, No. 6, 1713–1724 (June 1961); An additional note, J. R. Wait and A. M. Conda, J. Geophys. Research **66**, No. 6, 1725–1729 (June 1961).
Wait, J. R., Influence of source distance on the impedance characteristics of ELF radio waves, Proc. IRE **48**, No. 7, 1338 (July 1960).
Wait, J. R., On the calculation of AFMAG anomalies, Geophysics **25**, 1290–1293 (Dec. 1960).
Wait, J. R., On the electromagnetic response of a conducting sphere to a dipole field, Geophysics **25**, No. 3, 649–658 (June 1960).
Wait, J. R., On the excitation of electromagnetic surface waves on a curved surface, IRE Trans. Ant. Prop. **AP–8**, No. 4, 445–449 (July 1960).

Wait, J. R., On the theory of the slow-tail portion of atmospheric waveforms, J. Geophys. Research **65**, No. 7, 1936–1946 (July 1960).
Wait, J. R., Propagation of electromagnetic waves along a thin plasma sheet, Can. J. Phys. **38**, 1586–1594 (1960).
Wait, J. R., The electromagnetic fields of a dipole in the presence of a thin plasma sheet, Appl. Sci. Research **8**, Sect. B, No. 5–6, 397–417 (1960).
Wait, J. R., The electromagnetic fields of a horizontal dipole in the presence of a conducting half-space, Can. J. Phys. **39**, No. 7, 1017–1028 (July 1961).
Wait, J. R., Spies, K. P., A note on phase velocity of VLF radio waves, J. Geophys. Research **66**, No. 3, 992–993 (Mar. 1961).
Wait, J. R., Spies, K. P., Influence of earth curvature and the terrestrial magnetic field on VLF propagation, J. Geophys. Research **65**, No. 8, 2325–2331 (Aug. 1960).
Wait, S. C., Barnett, M., The calculation of the energy levels of nearly symmetric rotors, J. Mol. Spectroscopy **6**, 276 (1960).
Walker, R. F., Microbalance techniques for high temperature application, Book, Vacuum Microbalance Techniques, Ed. M. J. Katz, **1**, 87–110 (Plenum Press, Inc., New York, N.Y., 1961).
Walker, R. F., Efimenko, J., Lofgren, N. L., Rate of vaporization of refractory substances, Book, Physical Chemistry in Aerodynamics and Space Flight, p. 24–30 (Pergamon Press, Inc., London, England, Feb. 1961).
Wall, L. A., Aromatic fluorocarbons: thermal stability and synthesis, Proc. 6th Joint Army-Navy-Air Force Elastomer Conf., Oct. 18–20, 1960 (U.S. Army Quartermaster Research and Engineering Command, Natick, Mass.), **I**, 150 (1960).
Wall, L. A., Electron spin resonance studies of free radicals in irradiated materials, Symp. Materials in Nuclear Application, Am. Soc. Testing Materials Spec. Tech. Publ. **276**, 208–223 (1959).
Wall, L. A., Polymer decomposition: thermodynamics, mechanisms, and energetics, SPE J. **16**, Pt. I, 810–814 (Aug. 1960); **16**, Pt. II, 1031–1035 (Sept. 1960).
Wall, L. A., Donadio, R. E., Pummer, W. J., Preparation and thermal stability of tetrakis-(pentafluorophenyl)-silane and tris-(pentafluorophenyl)-phosphine, J. Am. Chem. Soc. **82**, No. 18, 4846–4852 (Sept. 1960).
Wall, L. A., Straus, S., Pyrolysis of polyolefins, J. Polymer Sci. **44**, 313–323 (June 1960).
Wallenstein, M. B., Krauss, M., Interpretation of the appearance potentials of secondary ions, J. Chem. Phys. **34**, No. 3, 929–936 (Mar. 1961).
Warwick, J. W., Lawrence, R. S., The use of interferometer observations of satellites for measurement of irregular ionospheric refraction, Ann. IGY **XII**, Pt. 2, 566–569 (1961).
Warwick, C. S., McDonald, N., Pohrte, T., A search for geomagnetic singular days, J. Geophys. Research Letter to Editor **65**, No. 9, 3013–3015 (Sept. 1960).
Washer, F. E., Tayman, W. P., Location of the plane of best average definition for airplane camera lenses, Photogrammetric Eng. **26**, No. 3, 475–488 (1960).
Watts, J. M., Davies, K., Rapid frequency analysis of fading radio signals, J. Geophys. Research **65**, No. 8, 2295–2301 (Aug. 1960).
Wegstein, J., From formulas to computer oriented language, Communications ACM **2**, 6–8 (1959).
Weitzel, D. H., Robbins, R. F., Bopp, G. R., Bjorklund, W. R., Elastomers for static seals at cryogenic temperatures, Proc. 1960 Cryogenic Eng. Conf. Book, Advances in Cryogenic Engineering **6**, Paper D–6, 219–227 (Plenum Press, Inc., New York, N.Y., 1961).
Weitzel, D. H., Robbins, R. F., Bopp, G. R., Bjorklund, W. R., Low temperature static seals using elastomers and plastics, Rev. Sci. Instr. **31**, No. 12, 1350–1351 (Dec. 1960).
Weldon, J. M., Shapley, A. H., Lincoln, J. V., Plan for geophysical alerts and special world intervals during 1961–1962, IGY Bull. **47**, 11 (1961).
West, E. D., Techniques in calorimetry. I. A noble-metal thermocouple for differential use, Rev. Sci. Instr. **31**, No. 8, 896–897 (Aug. 1960).
Wexler, A., Humidity standards, TAPPI **44**, No. 6, 180a (June 1961).
Wiese, W. L., Mechanical spectrograph shutter for extremely short exposure times, Rev. Sci. Instr. **31**, 943 (1960).
Wiese, W. L., Berg, H. F., Griem, H. R., Measurements of temperatures and densities in shock-heated hydrogen and helium plasmas, Phys. Rev. **120**, 1079 (1960).
Wiese, W. L., Berg, H. F., Griem, H. R., Measurement of the structure of strong shocks in helium-filled T tubes, Phys. of Fluids 4, 250 (1961).
Wildhack, NBS—source of American standards, ISA J. **8**, No. 2, 45–50 (Feb. 1961).
Wilson, A. C., Cottony, H. V., Radiation patterns of finite-size corner-reflector antennas, IRE Trans. Ant. Prop. **AP–8**, No. 2, 144–157 (Mar. 1960).
Wilson, W. A., Martin, K. B., Brennan, J. A., Birmingham, B. W., Evaluation of ball bearing separator materials operating submerged in liquid nitrogen, ASLE–ASME

Lubrication Conf., Oct. 17–19, 1960 (Boston, Mass.), Am. Soc. Lubrication Engrs. Preprint No. 60–LC4, 50–58 (1960).
Wilson, W. K., Mandel, J., Determination of carboxyl in cellulose—comparison of various methods—TAPPI—ACS–ASTM–ICCA subcommittee on determination of carboxyl, TAPPI **44**, No. 2, 131 (1961).
Wilson, W. K., Mandel, J., Determination of pentosans. Interlaboratory comparison of the aniline acetate, orcinol, and bromination methods, TAPPI **43**, No. 12, 998–1004 (Dec. 1960).
Woelfel, J. B., Paffenbarger, G. C., Sweeney, W. T., Changes in dentures during storage in water and in service, J. Am. Dental Assoc. **62**, No. 6, 643–657 (June 1961).
Woelfel, J. B., Paffenbarger, G. C., Sweeney, W. T., Dimensional changes occurring in dentures during processing, J. Am. Dental Assoc. **61**, No. 4, 413–430 (Oct. 1960).
Woodside, K. H., Ormsby, W. C., Surface area determination of kaolinite using clycerol adsorption, J. Am. Ceram. Soc. **43**, No. 12, 671–672 (Dec. 1960).
Wright, J. W., A test of a procedure for easy estimation of representative monthly electron density profiles for the ionosphere, J. Geophys. Research **65**, No. 10, 3215–3217 (Oct. 1960).
Wright, J. W., Comments on models of the ionosphere above $h_{max}F2$, J. Geophys. Research **65**, No. 9, 2595–2596 (Sept. 1960).
Wright, J. W., Some magnetoionic phenomena of the Arctic *E*-region, J. Atmospheric and Terrest. Phys. **18**, No. 4. 276–289 (Aug. 1960).
Wright, J. W., The CRPL electron density profile program: some features and early results, Proc. URSI–AGI Symp. (Brussels, Belgium, 1959), Book, Some Ionospheric Results Obtained During IGY, Ed. W. J. G. Beynon, p. 215 (Elsevier Pub. Co., Princeton, N.J., 1960).
Wright, J. W., The magnetoionic phenomena permitting observation of valley minima between the *E* and *F* regions in the arctic, Proc. URSI–AGI Symp. (Brussels, Belgium, 1959), Book, Some Ionospheric Results Obtained During the IGY, Ed. W. J. G. Beynon, p. 85 (Elsevier Publ. Co., Princeton, N.J., 1960).
Wright, J. W., McDuffie, R. E., The relation of $h_{max}F2$ to m(3000) *F*2 and hp*F*2, J. Radio Research (Japan), **7**, No. 32, 409 (1960).
Wyckoff, H. O., Comparison of national standards for roentgen measurement, Trans. IXth Intern. Congress of Radiology, p. 1315–1318 (1960).
Wyly, R. S., A review of the hydraulics of circular sewers in accordance with the Manning formula, Yearbook, Am. Soc. Sanitary Eng. **38**, 154 (1960).
Yokley, C. R., Shumaker, J. B., Jr., Stepless variable resistor for high currents, Rev. Sci. Instr. **32**, No. 1, 6–8 (Jan. 1961).
Youden, W. J., Graphical diagnosis of interlaboratory test results, Indust. Quality Control **15**, 24–28 (1959); Middle Atlantic Conf. Trans., Am. Soc. Quality Control, p. 196–206 (1959).
Youden, W. J., How to evaluate accuracy, Materials Research and Standards (ASTM Bull), **1**, No. 4, 268–271 (Apr. 1961).
Youden, W. J., National physical standards and design of experiment, Bull. Intern. Stat. Inst. **35**, 191–198 (1957).
Youden, W. J., Statistical design of experiments, Handb. of Physics, Ed. E. U. Condon and H. Odishaw, Chapt. 13, Pt. I, 1–165–1–168 (McGraw-Hill Book Co., Inc., New York, N.Y., 1958).
Youden, W. J., The sample, the procedure, and the laboratory, Anal. Chem. **32**, No. 13, 23A–37A (Dec. 1960).
Young, J. A., Taylor, J. K., Chemical projects, J. Chem. Ed. **38**, 6 (1961).
Zelen, M., Problems in life testing: factorial experiments, Trans. 13th Midwest Quality Control Conf., Kansas City, Mo., p. 21–23 (Nov. 1958).
Zelen, M., Severo, N. C., Graphs for bivariate normal probabilities, Ann. Math. Stat. **31**, No. 3, 619–624 (Sept. 1960).
Zimmerer, R. W., Mizushima, M., Precise measurement of the microwave absorption frequencies of the oxygen molecule and the velocity of light, Phys. Rev. **121**, No. 1, 152–155 (Jan. 1, 1961).
Zwanzig, R. W., Ensemble method in the theory of irreversibility, J. Chem. Phys. **33**, No. 5, 1338–1341 (Nov. 1960).
Zwanzig, R. W., Intermolecular forces from optical spectra of impurities in molecular crystals, Mol. Physics **3**, No. 4, 305–311 (July 1960).
Zwanzig, R. W., Nonequilibrium processes in isotopically disordered crystals. Dependence on degree of order, J. Math. Phys. **2**, No. 3, 370–373 (May–June 1961).
Zwanzig, R. W., Statistical mechanics of irreversibility, Book, Lectures in Theoretical Physics (Lectures delivered at the Summer Institute for Theoretical Physics, University of Colorado, Boulder, Colo., 1960), **III**, 106–141 (Interscience Publ., Inc., New York, N.Y., 1961).
Zwanzig, R. W., Theory of vibrational relaxation in liquids, J. Chem. Phys. **34**, 1931–1935 (1961).

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:

Ambler, Ernest, No. 2,982,106, May 2, 1961. Low temperature refrigeration apparatus and process. (Commerce.)

Bryan, Ray K., No. 2,945,922, July 19, 1960. Micro-adjustable switch. (Licensed to the United States of America as represented by the Secretary of Commerce.)

Corliss, Edith L. R., Burkhard, Mahlon D., and Koidan, Walter, No. 2,968,695, January 17, 1961. System for monitoring and controlling the motion of a sound source. (Commerce.)

Harris, William P., and Cooter, Irvin L., No. 2,960,652, November 15, 1960. Bridge method for the measurement of core losses in ferro-magnetic material at high flux densities. (Commerce.)

Hoffman, John R., and Carlson, Robert E., No. 2,962,706, November 29, 1960. Aerial Navigation aid. (Licensed to the United States of America as represented by the Secretary of Commerce.)

Hogue, Ephraim W., No. 2,946,046, July 19, 1960. Magnetic digital computer circuit. (Commerce.)

Lesti, Arnold, and Baechtel, Andrew R., No. 2,945,220, July 12, 1960. Analogue-digital converter. (Commerce.)

Minor, Irene C., and Bennett, John A., No. 2,984,101, May 16, 1961. Tape method for detecting fatigue cracks. (Commerce.)

Parkhurst, Douglas L., No. 2,955,467, October 11, 1960. Pressure-type tide recorder. (Licensed to the United States of America as represented by the Secretary of Commerce.)

Perls, Thomas A., and Kissinger, Charles W., No. 2,958,216, November 1, 1960. Resonant-beam calibrator. (Commerce.)

Plitt, Karl F., No. 2,985,609, May 23, 1961. Aqueous pressure-sensitive adhesive composition comprising polyvinylalcohol and a polyethylene amine, and method of making. (Commerce.)

Pummer, Walter J., Wall, Leo A., and Florin, Roland E., No. 2,967,894, January 10, 1961. Method for the preparation of aromatic fluorocarbons. (Army.)

Rabinow, Jacob, No. 2,961,093, November 22, 1960. Conveyor belt sorters. (Commerce.)

Reaves, John H., No. 2,955,246, October 4, 1960. Low capacitance power supply. (Commerce.)

Reaves, John H., No. 2,970,278, January 31, 1961. Direct-coupled amplifier construction. (Commerce.)

Reaves, John H., No. 2,978,658, April 4, 1961. Low capacitance power supply. (Commerce.)

Sargent, Jack, and Birnbaum, George, No. 2,964,703, December 13, 1960. Recording microwave hygrometer. (Commerce.)

Slutz, Ralph J., No. 2,953,774, September 20, 1960. Magnetic core memory having magetic core selection gates. (Commerce.)

Thompson, Moody C., Jr., Freethey, Frank E., and Waters, Donald M., No. 2,981,908, April 25, 1961. Cavity resonator. (Commerce.)

Weaver, Elmer R, No. 2,966,864, January 3, 1961. Refrigerator lock with inside release. (Commerce.)

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