Annual Report 1952

National Bureau of Standards

U. S. Department of Commerce

UNITED STATES DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS
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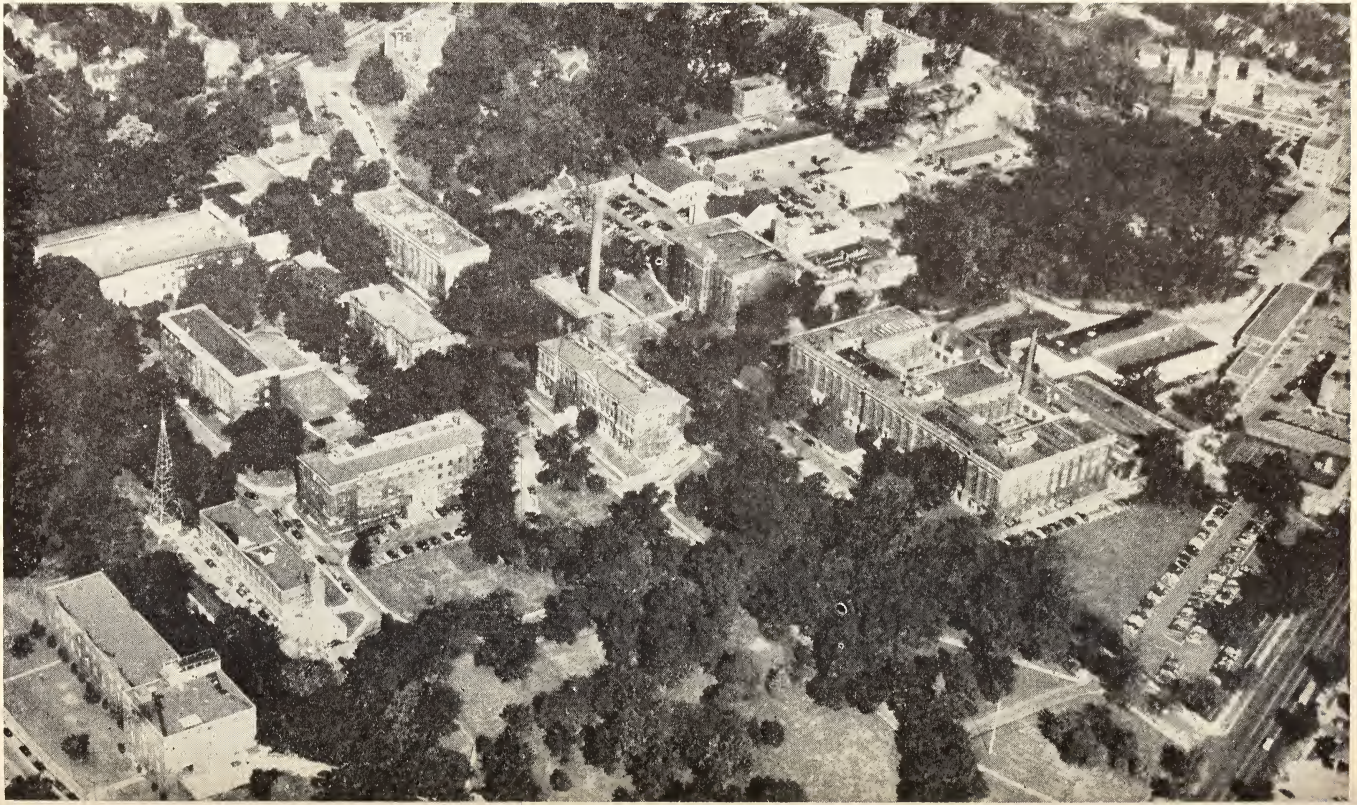
Annual Report 1952 National Bureau of Standards

Miscellaneous Publication 207

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 30 cents



Washington (D. C.) laboratories of the National Bureau of Standards

Contents

1. General Review

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

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

Most of the Bureau's work was conducted in its Washington, D. C., boratories. However, a growing amount of activity characterized the erations of the other three principal laboratories—at Corona and Los ngeles, California, and at Boulder, Colorado. The NBS Institute for umerical Analysis, located on the campus of the University of California, os Angeles, continued its well-established program in mathematical re-arch (particularly numerical analysis), computational services, and ectronic computer machine development and operation. The Corona aboratories, acquired during the preceding year from the Navy and suit-ly equipped, were in full operation with a staff totaling some 400 by the d of the year. The principal interests of this laboratory were missile ojects of interest to the Navy and ordnance work of interest to the Army, ong with work in electronics (e. g., automatic computers) and optics . g., infrared spectroscopy). At Boulder, a major cryogenic engineering cility was constructed for the Bureau by the Atomic Energy Commission. he installation was in full operation by the middle of the year. Mean-hile, a contract had been let for a major radio laboratory, to be erected n the Bureau's Boulder site and scheduled for completion by the spring of 954.

Typical activities during the year included the following: Thin, h
strength skin for high-speed aircraft was developed. The performanc
very large orifice meters was studied. A new titanium dioxide recti
was developed which has promising properties. A new method was dev
for sorting out atoms of unequal masses and accurately determining
tremely small differences in their atomic masses. A semi-portable ra
active cobalt source was developed for checking radiation instrument
the field. Various radioactive sugars and sugar derivatives were develop
The properties of blood plasma substitutes were studied—particularly
critical molecular weight. The properties of self-curing dental resins w
investigated. Progress was made in the electrodeposition of aluminum a
molybdenum. Improved ceramic dielectrics, important in electronics, w
developed. The physical and structural properties of cellular concr
were studied. Methods of solving large sets of algebraic equations w
studied. Studies of advanced, automatic electronic computers were und
way. The National Bureau of Standards Eastern Automatic Compu
(SEAC) was in operation 24 hours per day, 7 days per week, through
the year on important mathematical and scientific problems. The Burea
other computer (SWAC), after undergoing a test and proving-in period
now operating on a one-shift basis.

As a result of the rapid expansion of the radio frequency spectrum duri
the last war, considerable effort has been placed on exploring the natu
of radio waves at the higher frequencies, important for defense comm
nications and for such civilian applications as television. Regular servic
like the broadcast of radio frequency standards by the Bureau's static
WWV (Maryland) and WWVH (Hawaii) and the issuance of montl
radio propagation predictions (3 months in advance), have been continue
A North Pacific Radio Warning Service was established during the ye
for the Arctic regions; operating 24 hours per day, 7 days per week, t
service is necessary for reliability of radio communications in those regio
Extensive studies of the properties of radio waves between 94 and 1,0
megacycles have been conducted at the Bureau's Cheyenne Mountain st
tion. A new phenomenon of radio propagation by the ionosphere at t
higher frequencies has been discovered and is being intensively studie
Reflections from the moon were used to send a radio telegraph message.

A number of advances were made in the field of basic standards
science. Last year was the first full year in which the new NBS atom
standard of length was available to industry and other laboratories:
mercury-198 lamps were distributed. Wavelengths were determined
provide infrared standards, hitherto unavailable, important in analyzir
compounds, production control, and detection. Colorimetric specificatio
for a set of color standards for judging petroleum products were prepare
to replace the current obsolete standards. Considerable work was done o
the standardization of safety colors. The calibration of a 24-sided polygo
for calibrating in turn master angle blocks of industry, was completed.

One of the important services of the Bureau to business, industry, and vate laboratories is the comparison of working standards with the national ndards of measurement. More than 56,000 calibrations were performed the Bureau. Typical of this activity were the following calibrations: 388 stic calibration devices (proving rings, aircraft weighing cells, Amsler es, etc.), 743 water current meters, 474 timepieces, 8540 standard weights, 0 flasks, and 2500 hydrometers. Calibration and testing for the Govment included the calibration of more than 20,000 clinical thermometers mpled from 200,000 purchased) and the sample-testing of 15,800,000 rels of cement and 6,700,000 light bulbs. Approximately 30,000 standd samples (substances of known composition) were distributed to industry d private laboratories during the year while the Government itself used out 4000 units.

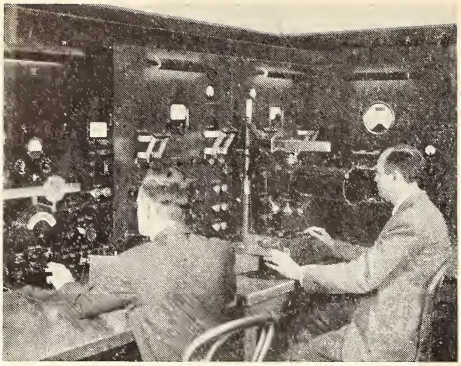
The total funds appropriated by Congress for the Bureau's basic program re 8.6 millions, consisting of 6.9 million for the technical activity and 1.7 llions for administration, shops, plant maintenance and laboratory renotions, etc.

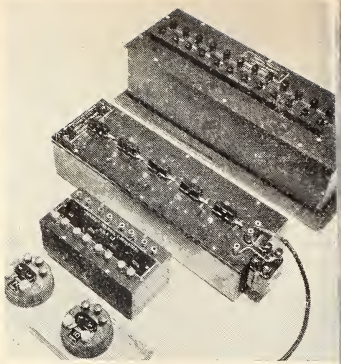
Several organizational changes were made in the Bureau's technical divin structure during the last year (see the end of this report for a list of visions and sections). An Associate Director was appointed to coordinate e Bureau's calibration and testing activities. The growth of the ordnance ogram made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

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

2. Electricity

The work in electricity is primarily concerned with the development and provement of standards and methods of electrical measurement, and udies of properties of materials that are important in electricity and magtism. The Electricity Division is also responsible for the dissemination of e improved standards to scientific and industrial laboratories. The quanties measured in the course of this work include electrical resistance, curnt, coltage, inductance, capacitance, energy and power. During 1952





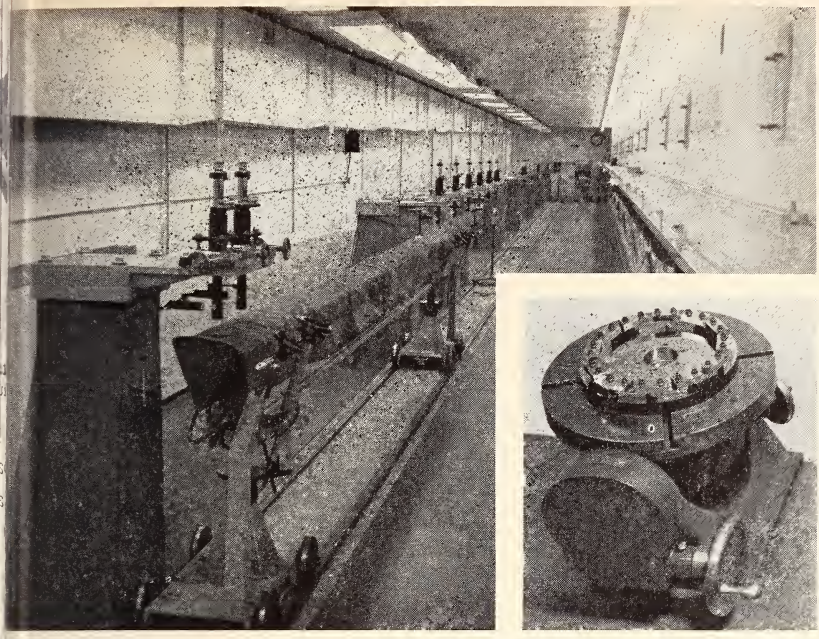
Left: standardization of an a-c voltmeter in the electrical instruments laborat Right: thermal converters and voltmeter elements used at the National Bureau Standards for testing ammeters and voltmeters at audio frequencies (p. 4).

considerable manpower was diverted to projects requested by the Depa ment of Defense. These included the determination of the electrical a magnetic properties of materials under extreme or unusual conditions quired for the development of new military devices.

Transfer Instruments for A-C Measurements

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

Thermal converters have long been used in thermocouple instruments moderate accuracy. The Bureau's study shows that converters which m special requirements can be used for a-c measurements by transfer metho with an accuracy approaching 0.01 percent. In the transfer method, instrument is calibrated with direct current, in terms of the fundamental c standards, immediately after each measurement with alternating curre Instruments may be designed for such service, as were these thermal transf instruments, to obtain increased precision of reading with little dependen on long-time stability and other secondary characteristics. Of fundament importance, however, is the ac-dc difference or transfer accuracy. Caref experimental studies of different types and ranges of available thermal co verters and a detailed intercomparison of converters with other types transfer instruments disclosed a number of factors which may limit th transfer accuracy of converters at audio frequencies. Theoretical evalu tions of these factors were correlated with actual measurements so that is now feasible to specify design characteristics needed for the require accuracy.



w tape-measuring tunnel where improved method for determining coefficients inear thermal expansion of geodetic tapes is used (p. 8). Insert: a twenty-r-sided polygon was constructed and calibrated (p. 8).

mputable Air Capacitor

Good progress has been made on the construction of an air capacitor of h design that its capacitance in electrostatic units can be computed with y high accuracy from measurements of its physical dimensions. Supple-ntary capacitors have been built for stepping up values based on these nputations by a factor of several hundred. These can then be compared h values obtained in electromagnetic units by measurements based on our ndards of resistance and frequency. This work, when completed, will ve two purposes: first, a determination of the ratio of the electrostatic to electromagnetic units which should be a measure of the velocity of light l, second, assuming that the velocity of electromagnetic waves is the ne at these low frequencies as at the frequency of light waves, an inde-ndent method for measuring the unit of electrical resistance in absolute ms.

3. Optics and Metrology

The activities of the Optics and Metrology Division include photometry l colorimetry, refractometry, optical and photographic technology, and applications of metrology which are most dependent upon optical meth-s. Calibration of line standards, interferometric measurements of length, l measurements of the coefficient of linear expansion are part of this rk. Noteworthy work of the division included an international com-

parison of photometric standards which showed the measurements r by the NBS to be gratifyingly near the mean of the results of five particip national laboratories. The division established color standards for p leum products and a dictionary of color names. Initiation of a progra measuring the index of refraction of optical glass and crystals over the e spectral range within which they are transparent, important applica of an interferometer with optical planes 10 inches in diameter, a new cedure of sensitometry applicable to photographic papers, and a new more convenient method for measuring the coefficient of expansion of veyors' tapes were also part of the division's work.

Color Standards for Petroleum Products

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

Dictionary of Color Names

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

By making use of a method of designating colors by 21 common ge terms (red, yellow, green, light, dark, and so on) developed at the Bu in 1939, this defect has been overcome. All possible colors are divided 267 groups, each identified by combinations (such as dark red or l green) of these generic terms. A dictionary, prepared at the Bureau the cooperation of the Inter-Society Color Council, lists alphabetically al 10,000 color names. It coordinates all the published information on c names used by American science and industry including mass-market na the color names used in textiles and plastics, those used by Federal age in the purchase of paint, those used in interior decoration, those used for colors of rocks and soils, and those used in biology, botany, horticulture, philately. Translations from one color language to another (such as Gri Viridis (biology) = *Serpentine* (fashion) = *Mint Green* (mass market

t green (ISCC–NBS)) are thus easy, and confusion and misunderading may be avoided.

damental Refractometry

echniques were developed for the measurement of indices of refraction rategically important optical media over their entire useful ranges includ- the near ultraviolet, visible, and infrared regions of the spectrum. The hods for the different regions are now as nearly the same as is feasible sidering the differences in the radiations and the different expedients t must be employed for their isolation and detection. In particular, the ly sensitive method of minimum deviation can now be employed, and -consistent data can be obtained for adjustments by dispersion equations. ndices of reflection of optical glass, lithium fluoride, potassium bromide, cesium bromide have been determined and published either in final entative form. The refractive uniformity of samples of annealed boroate optical glass was precisely determined by interferometric methods found to be as good as $\pm 1 \times 10^{-6}$ regardless of the annealing temature employed within the limits 490° to 530° C.

ctrophotometers

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

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

ercomparison of Secondary Standards

orty-five sets of intercomparisons of a group of ten of the Bureau's er bars were made, each bar being compared with all the others. The ervations were reduced by the method of least squares, and the probable or obtained from the comparisons was ± 0.03 micron. Computations e made using only 25 and then 30 sets in the reduction, and it was found t the computed lengths of the standards varied by a maximum of 0.04 ron from those lengths computed from 45 sets of direct comparisons. s indicates that a lesser number of direct observations need be taken that a high degree of accuracy can still be maintained.

Standard Angles

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

Optical Measurements on the Interferometer

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

Sensitometry of Photographic Papers

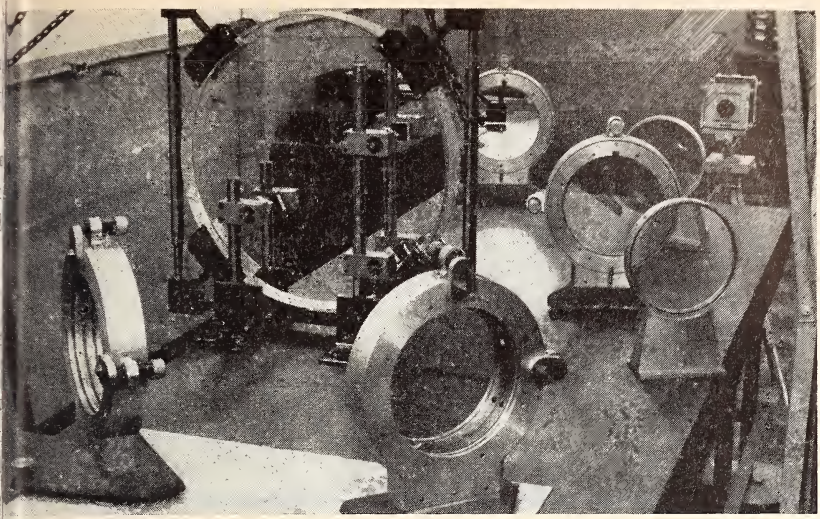
A new method of sensitometry, termed the bar-gamma method, application to photographic papers has been devised. The method p vides a simple, rapid means for evaluating papers with respect to l exposure scale and contrast (bar-gamma), and yields results which reproducible with high precision. An ASA standard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

Coefficient of Expansion of Surveyors' Tapes

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

Thermal Expansion

A long series of measurements of the coefficients of thermal expansi of selected aluminum alloys was completed and a number of papers pu lished. Part of the work consisted of investigating the relationship betwe chemical composition and thermal expansion.



new type of interferometer (p. 8) used to measure the variation of index of raction in large glass disks.

4. Heat and Power

To provide a fundamental basis for precise measurements of heat and wer, the Bureau has established and maintains a scale of temperature er most of the range from the lowest obtainable to the highest tempera- res of incandescent bodies and flames. NBS-calibrated platinum re- tance thermometers, thermocouples, and optical pyrometers are used as ndards in industrial and university research laboratories. This calibra- n service represents the only effective way of ensuring that the various oratories are employing the same temperature scale.

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

From these fields of research the work branches into engineering applica- ns: automotive and aircraft engines and accessories, high pressure pneu- atics, and cryogenic engineering. Basic lubrication studies are conducted the characteristics of fluids and bearings for use in mechanical equipment. ne Bureau is also responsible for determining and maintaining standards viscosity and for certifying the viscosities of fluids used for calibrating cometers. It maintains the primary standards for the determination of e octane numbers of automotive and aviation fuels. Research is con-

ducted to increase the accuracy of these standards and to develop
proved measuring instruments and apparatus.

Isotopic Determination of Water Content

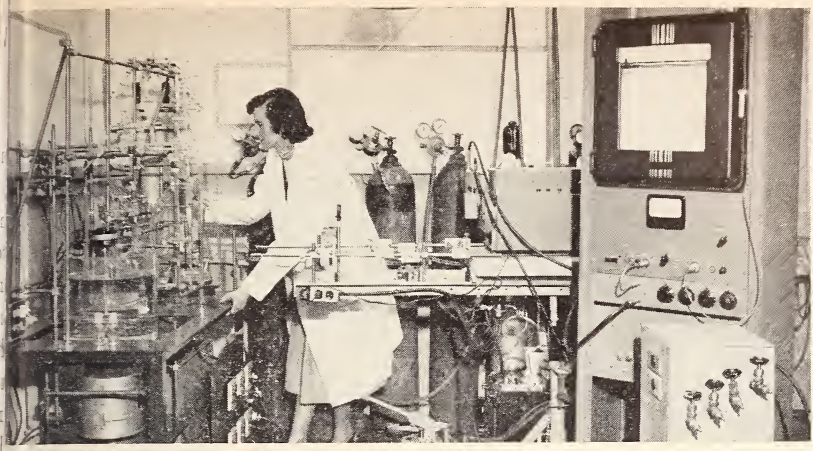
A method which uses heavy water to determine the total water con
of biological tissues and other materials was developed. This work
part of a program of basic instrumentation sponsored by the Departm
of Defense and the Atomic Energy Commission. Based on a spectrosc
measurement of the ratio of ordinary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

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

Properties of Gases

The systematic study and preparation of tables of thermal properties
a group of wind tunnel gases, fluorine compounds and, more recently, deu
rium compounds has been undertaken. The compilation and calculati
of tables of thermodynamic and transport properties of wind tunnel and
engine gases including oxygen, nitrogen, hydrogen, carbon dioxide, carb
monoxide, argon, and steam were completed. In all, 100 tables were calc
lated giving the compressibility, density, heat capacity, entropy, enthal
specific heat ratio, sound velocity, viscosity, thermal conductivity, and vap
pressure from low temperatures and pressures to 3,000° K and 100 atm
pheres. Particular attention was directed to the properties of air; cha
and tables were issued extending the known properties to pressures of 5,0
pounds per square inch.

Reports were issued on a comprehensive investigation of thermodynam
and related properties of fluorine and deuterium compounds. Heat capa



al water content of biological tissues and other materials is determined by an opic method (p. 10). A discharge tube (left) is scanned by a monochromator ght center), and the photoelectric recorder (extreme right) indicates the change he ratio of ordinary to heavy water (deuterium).

entropy, enthalpy, and free energy functions of ten simple fluorine nponds were calculated and reported from 100 to 5,000° K. Theo- ical analyses of the molecular data of several groups of related fluorine- ıtaining molecules are in progress. This work is complementary to an ɔerimental program on the same class of materials. The measurements lude determinations of the heat capacities of such substances as the flon polymer, the refrigerants Freon-12 and perfluoropropane, and three er important fluorine compounds. The ultimate objective of the experi- ntal and theoretical programs is to obtain a complete ensemble of thermal, lecular, and related properties of all simple and some of the more com- x compounds. The accumulation of such data should facilitate the solu- n of many problems arising from diverse uses of fluorine-containing mate- ls. These materials exhibit an extraordinary range of properties, e. g., y include some of the most stable as well as the most reactive and corrosive all known chemicals.

gh-Pressure Pneumatics

A pneumatics laboratory has been established with the cooperation of the vy Bureau of Aeronautics to further the development and technical evalu- ɔn of pneumatic systems and equipment. The need for greater economy utilization of weight and space in aircraft has led to new developments the pneumatics field. For example, although compressed air has been d for years, the trend is toward much higher storage and working pres- es as well as greater actuation speeds. Systems are now being designed pressures of 3,000 pounds per square inch and actuation speeds of a few lliseconds. Preliminary calculations indicate that storage pressures of)00 psi are justified and that perhaps even higher pressures may yield ther savings in weight and space, but with diminishing returns.

The pneumatics laboratory has placed in operation high-pressure, h
capacity facilities and developed instrumentation to study the pneum
of high-pressure, short duration, transient flow. It is now engaged in
technical evaluation of airborne pneumatic systems and individual c
ponents such as actuators, pressure reducers, special purpose valves, sto
reservoirs, and other related equipment. The laboratory is also conduc
parallel theoretical and experimental investigations on the phys
phenomena associated with the thermodynamics and mechanics of f
flow.

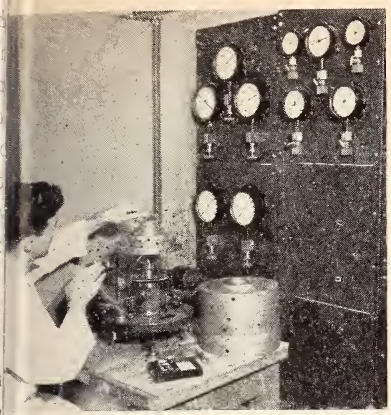
Low-Temperature Physics

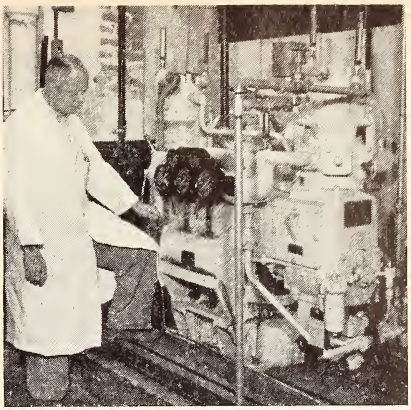
During the past year the National Bureau of Standards low tempera
laboratory expanded its research program to include the investigatio
magnetic properties of paramagnetic salts. Research on superconducti
and properties of liquid helium was continued. Facilities were prepa
for the production and storage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

The attainment and measurement of temperatures of the order of a
thousandths of a degree Kelvin are now possible at the National Bur
of Standards through the installation of a large electromagnet, a precis
mutual inductance bridge, and associated apparatus. This program p
vides a method for extending the NBS temperature scale down to the ra
of few hundredths or thousandths of a degree on the absolute scale. T
equipment, utilizing the cooling effect of demagnetization, was designe
the Bureau.

In the field of superconductivity, investigation of the isotope eff
continued and developed along several lines. The discovery of t
phenomenon in 1950 demonstrated a connection between the isotopic c
stitution of a superconductor and the superconducting transition te
perature. It was shown that the heavier isotopes of a given elem
become superconducting at lower temperatures than the lighter ones. T
knowledge has led to a better understanding of the nature of the sup
conducting state and has stimulated theoretical physicists to suggest n
and promising theories of superconductivity. Special apparatus and p
cise techniques developed for this work were used to complete a study
thallium isotopes. The results have been in general agreement with th
obtained earlier with tin isotopes.

The investigation, in collaboration with the Argonne National Lab
ratory, of thermal wave propagation in a 4-percent mixture of the ra
isotope helium 3 in ordinary liquid helium 4 contributed new results. T
measurements, carried out by means of the NBS-developed therm





t: dead weight gage (left center) used to calibrate pressure gages (on panel) the new pneumatics laboratory (p. 11). Right: air compressed to 3,000 unds per square inch is furnished by this compressor (p. 11).

ayleigh disk method, showed wave velocity of the thermal wave to be creased by the presence of the helium 3 impurity, down to the lowest mperature of 0.9° K. This result is of fundamental significance to the e played by statistics as absolute zero is approached. The disk obser- tions also provided measurements of the kinetic energy density of thermal opagation, showing a marked reduction due to presence of helium 3, as edicted. The torque determinations with the disk also provided the first ecific heat measurements for the mixture, in good agreement with the eoretical values.

brication Studies

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

The problem of lubricating bearings and the reduction gears in turbo- op engines operating at extremes of temperature is of considerable interest the military services. To determine the properties of these lubricants, e Navy Bureau of Aeronautics sponsored a project to investigate the use the Modified SAE and the McKee Extreme Pressure Lubricants Testing achines for determining the antiwear and the load-carrying properties turbo-prop lubricants. These machines use two contacting cylindrical st cups which are rotated under load at different speeds to give combined lling and rubbing action typical of gear teeth. Methods were developed hich show promise for controlling the anti-wear and load-carrying prop- ties of turbo-prop lubricants. Thirty-five lubricants were tested. With

regard to low viscosity at low temperature, high load-carrying capacity, wear, and good stability at high temperatures, some of the additive-t synthetic oils are superior to mineral oils and appear to be suitable for as turbo-prop lubricants.

Cryogenic Engineering Laboratory, Boulder, Colorado

This year saw the completion of the construction and putting into regu operation of the world's largest liquid hydrogen plant and cryogenic labo tory on the Bureau's site in Boulder. The capacity of the plant is 320 li of liquid hydrogen per hour. The hydrogen liquefiers and the purifiers the hydrogen are in duplicate so that the plant can be operated conti ously without shutdowns. The hydrogen liquefiers and purifiers were signed and constructed by the Bureau. The liquid hydrogen plant is s plied with liquid nitrogen from two 10,000-liter storage containers wh are filled by two liquid nitrogen generators each producing 250 liters hour.

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

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

Jet Engine Fuels

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

A project is nearing completion in which several hydrocarbons havi different structures were synthesized and studied to determine which ty of compound satisfied the requirements of a jet fuel to the greatest exte In complementary studies the compounds prepared were used in the Clev land Laboratory of the National Advisory Committee for Aeronautics in study of the mechanism of flame propagation. Precise physical constar were measured at NBS; in several cases the unusual structure of t compound warranted measurement of its thermodynamic properties.

Almost every conceivable type of aliphatic hydrocarbon has been repre-ited in these syntheses. These compounds were purified by fractionation ocedures which resulted in products of very high purity. Some of the mpounds were unknown prior to this work, and several new methods and hniques in organic syntheses were developed.

s Turbine Combustion

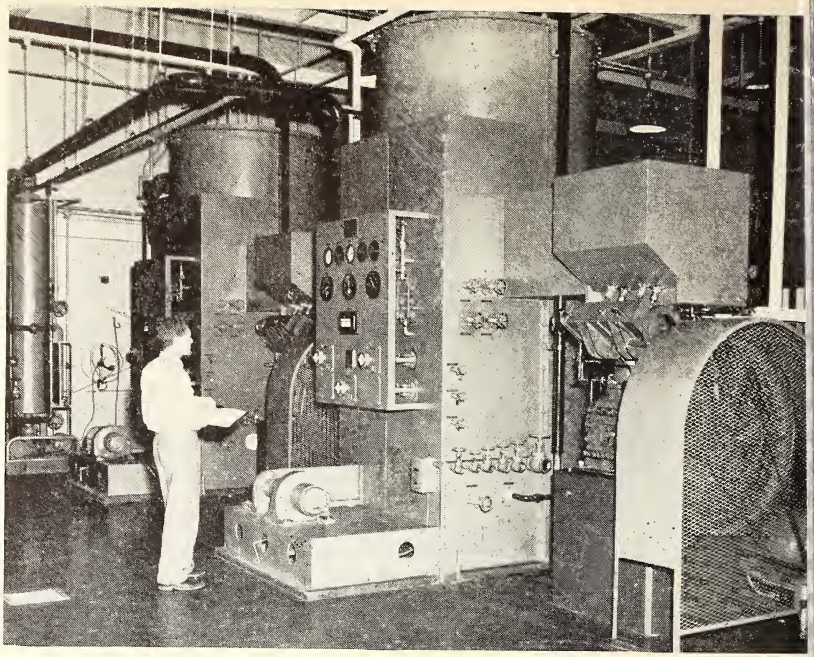
Problems of gas flow, heat release, and mixing in combustion chambers ve been investigated analytically and experimentally for the purpose of taining basic data applicable in designing gas turbine burners. These dies are based on an idealized or equivalent burner producing the same d result as an engine combustor. Mechanical means were used to con-l the ratio of the air taking part in the burning to that which is later xed with the flame gas. Observed values of pressure drop in the burner, e efficiency of combustion, and the rate of mixing of flame gas and ondary air were found to agree reasonably well with values predicted the analytical treatment, which appears to afford a sound basis for nbustor design.

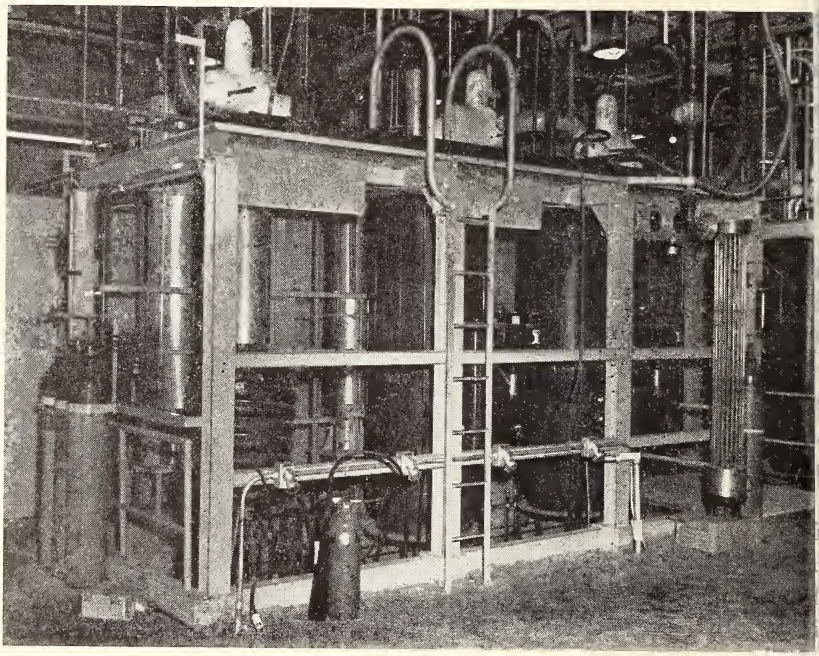
Engine Thermocouple

A thermocouple designed for flight service in jet engines in which the mperatures of the gases are above the range of conventional thermocouples s been developed. The new unit, useful to 3,700° F, has thermoelements ade of irridium and an alloy of irridium and rhodium. The insulating aterial is thoria, and the uncooled supporting tube is molybdenum, pro-ted from oxidation by a coating of molybdenum disilicide. The thermo-ments retain their mechanical strength and stiffness at the highest erating temperature and do not bend even when immersed in hot gas eams moving at the velocity of sound. Their principal disadvantage s in their relatively low thermoelectric power, but it is large enough to measured accurately by modern potentiometer indicators or recorders. he thoria insulation maintains its high electrical resistance, even in the mperature range in which the more commonly used porcelains become nducting. The silicide coated protecting tubes have a limited life at 00° F, but this life is considerably in excess of the duration of flight the applications for which the unit was designed.

5. Atomic and Radiation Physics

The results of atomic and nuclear research are of importance to research oratories, medical institutions, industry, the military services, and other overnment agencies. The program of the Atomic and Radiation Physics vision is primarily concerned with studies of (a) fundamental particles ch as atoms, nuclei, neutrons, and electrons (beta-rays), (b) properties radiations, particularly gamma- and X-rays and ultraviolet, visible and rared light, and (c) the interactions between such radiations and par-les. Emphasis is placed on the fundamental research and development





The NBS Cryogenic Engineering Laboratory, Boulder, Colorado, was comple
(p. 14). Top: nitrogen liquefier room. Bottom: hydrogen liquefier room.

essary to meet the ever-increasing demand in these branches of physics new standards, more accurate values of atomic and nuclear constants, able data on the properties of high-energy radiations, new and improved hods of measurement, and the calibration of sources of radiation and nstruments used for detecting these radiations.

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

anium Dioxide Rectifiers

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

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

asurement of Atomic Masses

A new method has been devised for sorting out atoms of unequal masses l accurately determining extremely small differences in their atomic

masses. This is accomplished by measuring the time-of-flight of par
passing through crossed electric and magnetic fields. The method e
tively combines the principle of resonance, as utilized in a cyclotron fo
acceleration of particles to high energies, with the conventional analyz
a mass spectrometer for separating atomic masses. The resulting in
ment has distinct advantages over either a mass spectrometer or cyclo
because it surmounts several limitations which restrict the accuracy attain
by using either method separately. The measurement of heavier m
has in the past been especially difficult and severely limited in accur
the new method appears to be most effective for heavier masses and
demonstrated greater power to separate atoms of very slight mass-differ
than any previous mass spectrometer.

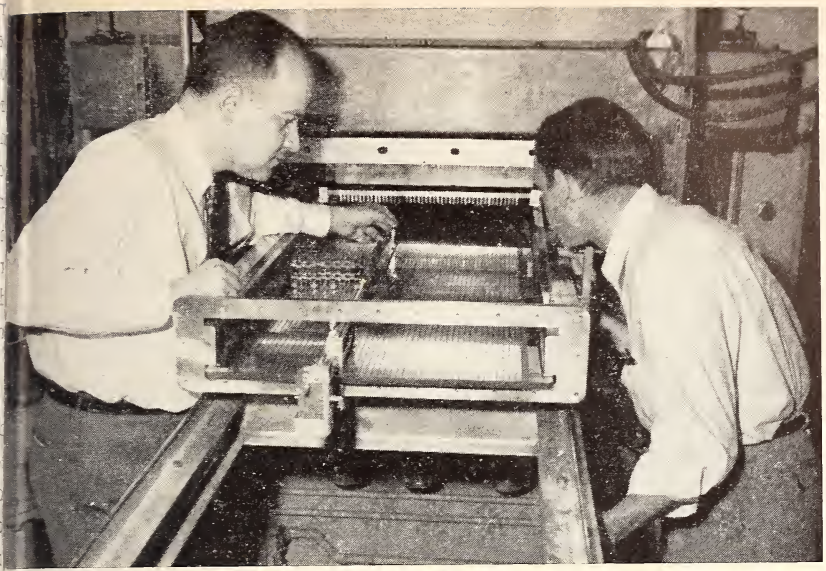
The utmost precision in determining atomic masses is essential for
ther development of atomic energy programs and for future researcl
nuclear theory. The importance of mass values arises from the basic e
tion used in calculating the amount of energy released in a nuclear reac
or in checking theories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

Solid State Physics

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

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

Work at the NBS led to the recognition that these imperfections shou
influence the absorption of mechanical energy by the crystal, and p
liminary tests completed about a year ago showed that the effect could
observed. During the past year a new instrument that makes these measu
ments rapidly and precisely was devised and placed in operation. T
principle of the method is simple; the crystal, in the form of a bar mount
on nearly frictionless supports, is set in vibration and the time requir



new method has been devised for sorting atoms of unequal masses (p. 17). ıe analyzer of the new mass spectrometer now under construction is partially moved for inspection.

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

lpha-Helium Scattering

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

Cobalt-60 Source

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

Betatron Program

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

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

Radiometry of Fluorescence

The extensive adoption of fluorescent lighting during the last 15 yea for household, recreational, commercial, and industrial uses has arouse interest in its relationship to colors, e. g., in paints, fabrics, chemical rea tions, and even the appearance of food. The spectral quality of the radiar

gy from the lamp determines its usefulness and suitability in a particular ication. Experiments conducted during 1952 resulted in the develop- t of a method and associated equipment for use in precise evaluation ie spectral energy distribution of fluorescent lamps.

etration of Gamma Rays

ccompanying the increased use of radioactive materials in industrial arch and medicine is a growing concern for the harm radiations from e materials can inflict on personnel. To aid in reducing these dangers minimum, the National Bureau of Standards, in cooperation with the ce of Naval Research and Atomic Energy Commission, has been con- ing a theoretical and experimental investigation of radiation shielding ces. This particular program is devoted largely to studies of the dis- e radiations travel from their sources and the transformations they ergo during the process. The experimental phases of the work are gned to yield information that is essentially general in nature but which be readily adapted to specific problems. Whenever possible, the experi- ts are carried out on a small scale or on a model. In this way, a wide ety of investigations can be made of the protection problems associated devices such as very large nuclear reactors. Ultimately, the accum- ed data will form a basis from which radiation barriers of the correct ness and material may be designed for economical and safe protection.

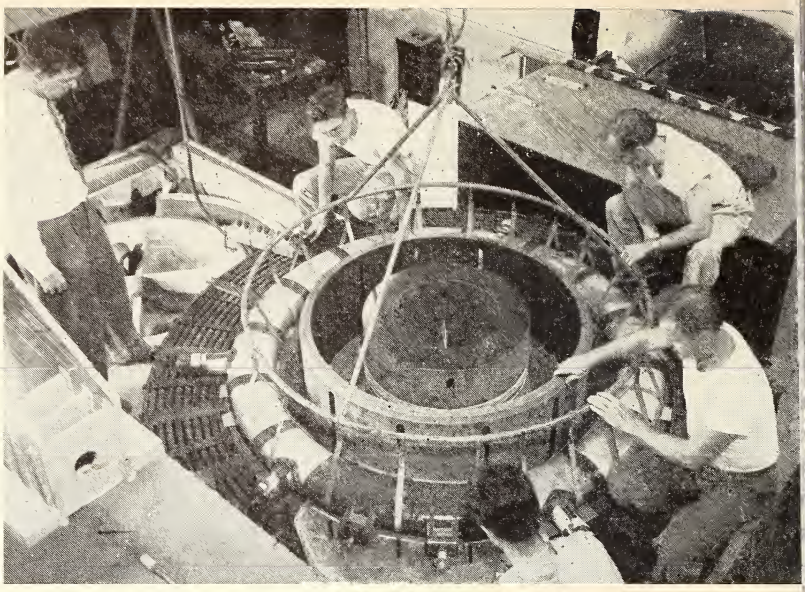
tographic Film Dosimeter

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

iation Data

he NBS report *X-Ray Attenuation Coefficients from 10 Kev to 100 Mev,* ished in May 1952, constitutes the first of a contemplated series of eys and tabulations of information on various problems of radiation ics. Radiation physics has grown from a branch of basic atomic re- h into an important element of all atomic-energy activities and of large ches of biology and medicine. This broad range of application empha- the need for tabulations of radiation data, supplemented by elementary ductory statements of the principles underlying the phenomena under ideration. Moreover, the preparation of adequate tables of numerical often requires much new research.

-ray attenuation coefficients were tabulated from 23 materials including water, and concrete. The most commonly used materials were chosen abulation. However, it is possible to obtain coefficients for an element



Installing the "doughnut" of the new 180-million-volt synchrotron. Mag field measurements and component testing of the synchrotron are virtually plete (p. 20).

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

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

Wavelengths for Infrared Standards

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

plex Spectra

he analysis of complex spectra supplies the physicist, the chemist, and astronomer with atomic data that are needed in the interpretation of erous laboratory and stellar problems. During 1952 the Bureau prac- y completed three such analyses that have been in progress for more thirty years. In the first spectrum of chromium, Cr I, more than characteristic radiations were measured for wavelength, their in- ties were estimated, and the behavior of many of them in high netic fields was studied. Similar results were worked out for more 2,000 radiations that constitute the second spectrum of chromium, . These data were used to derive, for the neutral and singly ionized mium atoms, the energy states upon which the designations of the ral radiations are based, and the amount of energy required to detach, essively, a valence electron from the atom and ion. In the first rum of molybdenum, data on wavelengths, intensities, and magnetic rns have been compiled for nearly 9,000 characteristic radiations. use molybdenum is chemically a homologue of chromium, their spectra ld be similar and, in general, this was found to be the case.

ared Spectroscopy

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

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

6. Chemistry

wide range of research is conducted in physical, analytical, organic, inorganic chemistry. Special laboratories are devoted to organic pro- ve coatings, detergents and absorbents, carbohydrates, metals and s, pure substances, electrodeposited coatings, gases, and acid-base ators and pH standards. Representative activities included the de- pment of new methods of chemical analysis, studies of the nature and

causes of chemical reactions, determination of the physical constan substances of interest to science and industry, and development of sp cations for commodities used extensively by the Government. Most c NBS standard samples, critical in industrial quality control and in rese originate in the Bureau's chemical laboratories. There was a ma increase during the year in the research conducted for the Departme Defense. Also increasing effort had to be given to the standard sa service and to consultative and advisory services for other Govern agencies.

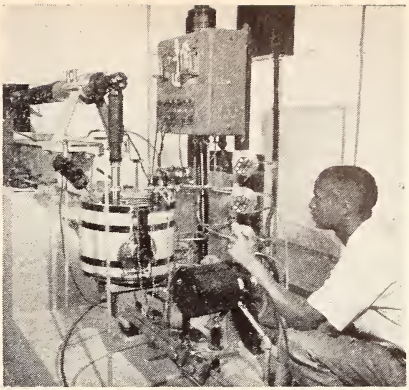
Structure in Detergent Solutions

One of the most interesting and widely investigated problems in co chemistry is that of the determination of micelle size and shape in dete solutions. Although a program of study of structure in detergent solu is intended primarily to advance understanding of detergents and detergent process, the results of such investigations are applicable to a extent to a host of other industrially important surface-active substa In addition, detergents can be considered as one of an increasingly portant group of materials—the water-soluble polymers. During 195 Chemistry Division concluded a viscometric study of dilute aqueous soc dodecyl sulfate solutions. This work lends support to the view that micelles in this system are spherical.

Labeled Sugars and Sugar Derivatives

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

During the current year methods were perfected for the preparatio 12 more C^{14}-labeled sugars and sugar derivatives. Substantial quantitie these substances were distributed for research in biology and medic Methods were published for the preparation of glucose-1-C^{14}, mann 1-C^{14}, fructose-1,6-C^{14} and lactose-1-C^{14}. Significant improvements w made in methods for the preparation of D-arabinose-1-C^{14}, D-ribose-1- D-fructose-1,6-C^{14}, D-glucuronic acid-6-C^{14}, D-glucose-6-C^{14}, and D-arabin 5-C^{14}. Simple methods were developed for the assay of C^{14} in the term positions of reducing sugars. The value of reaction with radioac cyanide for the determination of minute quantities of reducing sugars indicated and analytical procedures were devised.



Bureau is investigating the use of dextran as a blood plasma substitute (p. 27). dextran solubility in methanol-water solutions is tested by dropping methanol burette into water solutions of dextran. Right: equilibrium ultracentrafuge center) used in study of blood plasma substitutes and other high polymers 7).

ganic Compounds

norganic chemistry is assuming increasing importance because of the d adoption by industry of many new inorganic compounds. Particu- in the field of metals, where new uses and shortages have driven poten- users to seek substitutes and new materials, more detailed knowledge of chemistry of newer metals is needed. Continuing work is needed to uire chemical knowledge of metals like titanium, a light metal which is trong as steel and corrosion resistant, and zirconium, a strong heat- tant material used in atomic piles. Several contributions were made his field by the Bureau during 1952. One was to the analytical chemistry itanium, zirconium, silicon, barium, strontium, calcium, magnesium, ninum, and iron through the development of a reliable method for rmining the chemical composition of titanate dielectrics. An outstand- feature of the method was the discovery of an extremely sharp separa- of barium from strontium. This same reaction effected the prepara- of strontium-free barium salts and of barium-free strontium salts.

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

new method for preparing cobalt-free nickel salts made available for irst time nickel salts suitable as standards for measurement of magnetic eptibility, spectrochemical analysis, and for developing testing methods ickel salts as reagent chemicals. In this connection the potentiometric tion of cobalt in nickel salts by means of ferricyanide was extended to ntities as small as 2 micrograms in the presence of one million times as h nickel.

method was devised for freeing zirconium of common impurities and reparing zirconium sulfate and oxide.

Dissociation Constants

In connection with the Bureau's program for establishing pH s ards, a procedure was developed for the resolution of overlapping diss tion constants of polybasic acids and, hence, for determining the com tions and pH values of solutions of salts of these acids. The metho been applied successfully to the determination of the constants of D-ta acid and, in modified form, to phosphoric acid over the range of tem tures ordinarily encountered in pH measurements. These acids and salts are widely used as constituents of buffer solutions for the regul of acidity. The determination of accurate values of their dissociation stants is expected to be of practical as well as of theoretical applicatio

Chemical Thermodynamic Properties

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

Pure Substances

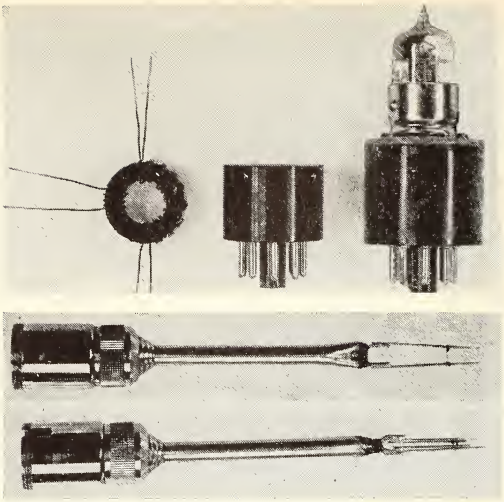
The evaluation of purity of chemical substances that are "nearly" has been less successfully handled in the past than the analysis of c mixtures or the assay of extremely pure compounds. Even in the l case, little indication is usually attained about the nature of impurities. cent developments in the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

od Plasma Substitutes

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

7. Mechanics

esearch work in the field of mechanics includes fundamental mechanics olids, liquids and gases, improvements in the precise measurement of hanical quantities such as density, mass, force and pressure, investi- ons in the field of aerodynamics, acoustics, structures and hydraulics, selected instrumentation and apparatus. Investigations in progress uded architectural acoustics, measurement of sound pressure at low quencies, and precise measurement of pressures up to 200,000 psi (for lication in military work and the chemical industry) and of pressures ow 0.0000001 psi for aeronautic and laboratory use. Other studies ude the measurement of turbulence with hot-wire anemometers at speeds ow and above the speed of sound, the impact experienced by an airplane anding, the measurement of backflows of salt water along the beds of



Right: the speed of sound in a liquid contained in a cell (arrow) is measured
tinuously by the ultrasonic velocimeter (p. 28). Top left: a pulse transfo
wound on a ferrite toroid (left) for use in a blocking oscillator (right) havin
rise time (p. 28). Bottom left: two types of hot-wire anemometer heads us
the Bureau in aerodynamic research (p. 29). The wires, 0.0002 inch in dian
are soldered between the needle-point prongs.

rivers, and the performance of the very large orifice meters now requ
by the natural-gas industry.

Sonic Measurement of Physical Properties

With the increasing use of automatic process controls by industry,
methods for measurement of physical properties are needed. Two
instruments reported last year continued under development during 1
One is an instrument for measuring, by an acoustic technique, the visc
coefficients of gases; the other is a device for measuring and recor
continuously the velocity of sound in a liquid. A by-product of t
investigations was a very fast blocking oscillator, having a rise time of
than 0.02 microsecond and a duration of less than 0.06 microsecond.

Sound Reverberation

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

Viscosity of Gases

Several measurements of the viscosity of gases, sponsored by the Natic
Advisory Committee for Aeronautics, were made on apparatus develo
in previous years. Measurements were made on a sample of gaseous c
bustion products at a temperature in excess of 2,000° F at approxima
atmospheric pressure. Almost no reliable data on the viscosities of g

his and higher temperatures are available. They are particularly useful developing aircraft engines in which both the temperatures and gas ocities are high. Measurements conducted on dry air under pressures to 300 atmospheres and temperatures up to about 600° F and on moist over a less extensive range of temperature and pressure agree closely h values believed to be the best previously available.

t-Wire Anemometers at High Speeds

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

igue Strength of Structures

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

The relationship between the fatigue strength of the basic materials and fatigue strength of aircraft structures is of particular importance because ght limitations make the efficient use of materials essential. At the uest of the Bureau of Aeronautics, a program of tests designed to deterne the relation between fatigue life of a simple structure and that of pons made from the same material has been completed. Seven simple ted beams, constructed by an aircraft manufacturer, were subjected to eated bending loads in a specially designed machine. This machine pered varying the deflection of the middle of the beams with respect to the ls to produce failure in from 1,200 to 500,000 cycles. Stresses in the ge were computed from the measured loads required to deflect the beams. ooth coupons of the material used in the beams were tested over the same range under repeated axial load and the corresponding stress-life relation-

ship determined. The results showed that the beams were about h
strong as the basic material for failures at the same number of cycles i
range from 1,200 to 500,000 cycles.

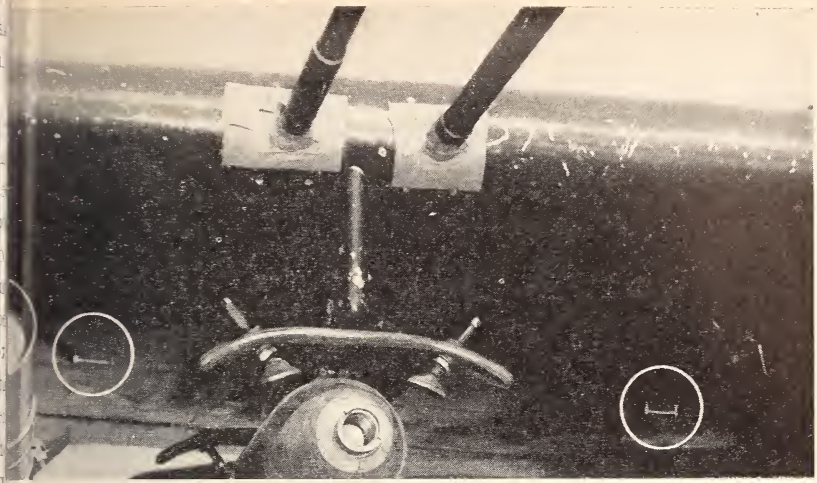
Another difficulty in predicting the behavior of structures in service
results obtained in standard laboratory fatigue tests is due to the u
fluctuating loads of constant amplitude in the standard test, where
service the maximum load varies widely from cycle to cycle. An air
for example, usually has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

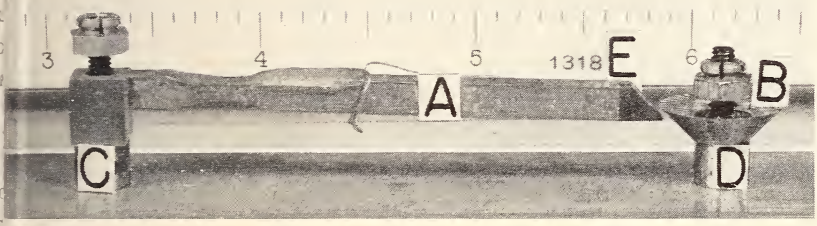
Stiffened Skin for High-Speed Aircraft

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

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

Tests were conducted to determine the effect of temperature on
strength and distortion of wing panels of the above sandwich type an
other high-strength types. It was found that, at a uniform elevated t
perature, the strength was 20 to 30 percent below the strength of the pa
tested at room temperature. Temperature gradients through the pa
thickness were found to cause some warping of the specimens but to leave





o: limit-load gages (circled) installed on the underside of the wing of a F8F mman "Bearcat" (p. 31). (Photo courtesy of United States Marine Corps.) Idle: side view of partially assembled NBS limit-load gage showing its three or components: the arm (A), cam (B), and gage points (C and B).

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

nit-Load Gage

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

Pressure Drops in Oxygen Flow Systems

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

Laboratory Centrifuges

An ultrahigh centrifuge has been completed. This centrifuge is cap of producing an acceleration of 60,000 *g* on a 1-lb weight. Prior to development of this equipment, stresses of this magnitude could no produced in laboratories. A second centrifuge has been developed to heavy items. This centrifuge will produce acceleration forces of 1(on equipment weighing 100 lb. This centrifuge allows testing of compl units.

Four-Inch Air Gun

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

High-Capacity Load Calibrating Devices

The calibration of four 3,000,000-pound-capacity compression dy mometers for use in calibrating large testing machines has been complet These dynamometers can be used together to measure forces up to 12,0(000 lb. Prior to the development of these dynamometers, which make of attached wire resistance strain gages as a part of their load-indicati systems, the highest load which could be accurately measured was appro mately 2,600,000 lb. It is expected that the new dynamometers will be us to calibrate a considerable number of the larger testing machines at reduced cost and a saving in time.

e Dam-Break Problem

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

nsity Currents

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

8. Organic and Fibrous Materials

The Bureau investigates rubber, plastics, textiles, leathers, and papers. ese natural and synthetic materials are considered nondepletable re- rces and are of great importance to the national economy. The textile ustry is the nation's second largest while the comparatively new field of stics has already assumed fifth place in size and is still growing. These organic materials have certain common characteristic properties due he long, chain-like structure of their molecules. The complex molecular ucture of high polymers, combined with their refusal in many cases to ow the laws of classical physics, has made it very difficult in the past to ain definite fundamental knowledge of their properties. In recent years, wever, rapid progress has been made in the science of high polymers, and v techniques have been developed for measuring their properties and

studying their reactions. Many of the new techniques—such as X-ray fraction, infrared spectroscopy, and electron microscopy—are being ployed by the Bureau to obtain a better understanding of the fundam properties of high polymers, both natural and synthetic.

The research program has included studies of rheological properti synthetic polymers, physiochemical structure of fibers, chemical natu collagen, chemical reactions involved in the deterioration of polyn materials, and structure of human tooth enamel and dentin. Applie search on polymeric materials included efforts to make papers and pla having properties outside the range of those previously thought pos Significant contributions have been made in applications of polymeric terials to windows on aircraft, structural laminates reinforced with fiber, self-curing resins for dentures and dental fillings, and sole leath improved abrasion and fungus resistance. Research was also undert to extend the uses of organic materials to replace metals and other stances that are in even shorter supply. The reopening of the Gov ment synthetic rubber plants greatly increased the demand for stan rubber samples and called for investigations leading to better metho quality control.

Deformation of Elastomers

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

Structure and Composition of Collagen

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

Structure of Cotton Fibers

The extent to which the available surface of cotton increases when contact with water is believed to influence the behavior of the fiber duri processing and use. As a part of an investigation on the structure of cott

rs, surface area measurements were made on a number of cottons that been stabilized, in the expanded condition resulting from swelling in er, by a process of solvent exchange. Surface areas, calculated from quantities of nitrogen adsorbed at low temperature by the expanded cot-s, ranged from 4 square meters per gram for a partially methylenated on to 148 square meters per gram for a mercerized cotton of low ma-ty. Purification and mercerization resulted in increases in the surface ilable after swelling, methylenation produced a decrease, ethylamine atment had no effect. The results indicate that the method will prove ful in evaluating the effects of various treatments on cotton and other ulose fibers.

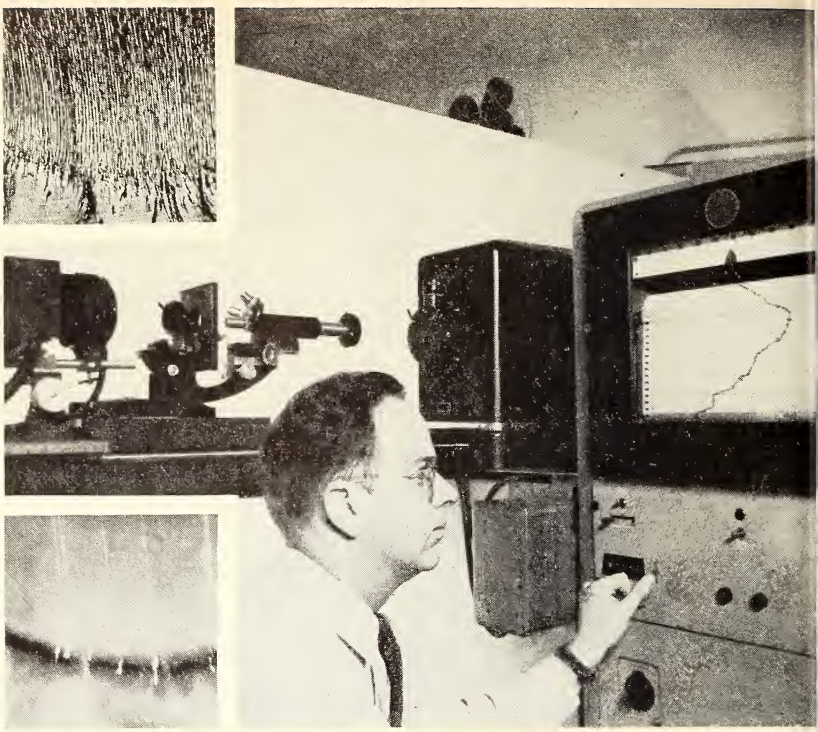
ucture of Tooth Enamel and Dentin

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

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

f-Curing Dental Resins

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

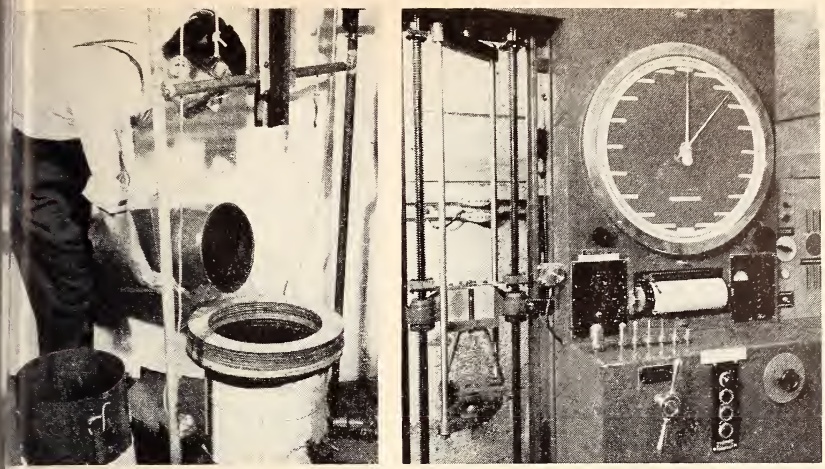


Natural fluorescence of human teeth reveals new details in tooth structure (p. 3
A recording spectrometer (center) is one device used to analyze fluorescer
The spectral intensities of various areas of a tooth section being subjected to ul
violet light (far left) are automatically recorded on the chart at right. Top in:
shows a dentin-enamel junction in a tooth section photographed under visible li
Bottom insert shows a tooth section excited to fluorescence by ultraviolet li

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

Glass-Fiber Reinforced Plastics

The use of glass-fiber reinforced plastics has increased greatly in
last few years. The armed services have found this type of mate
adaptable to scores of applications, such as radomes and other parts
aircraft, containers, boats, prefabricated shelters, skis, and toboggans. T
variety of applications requires many data on design and production qua
control. Under the sponsorship of the NACA and the Wright Air Devel



t: sheet of aircraft glazing, stretch-formed in the shape of a hat, is removed from acuum forming vessel (p. 38). Right: apparatus used for determining the sting strength of leather (p. 37). Plungers used in the tests are on the machine nel.

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

iffness of Paper

The stiffness of paper is a property of importance in a wide variety of uses, such as case liners for shipment of military materials, cards for e in mechanical punched-card systems, and currency paper. Heretore there has been no very satisfactory method for measuring this property. new instrument for determining this property has therefore been deloped at the Bureau. In the NBS device, the specimen is bent through given angle, and its stiffness is measured as the torque in a wire suspension. y varying the size of the supporting wires and the angle through which e specimen is bent, papers having a wide range of stiffness can be tested ithout difficulty in whatever dimensions they happen to be available. he NBS Stiffness Tester is also expected to prove useful in testing the iffness of such materials as thin plastic sheets and textiles.

urst Test for Fibrous Sheet Materials

For many years the Mullen tester has been used for measuring the burstg strength of fibrous sheet materials, particularly paper and leather. Yet ne use of this device has been continually accompanied by difficulties. uring the year two research projects intended to obviate such difficulties ere completed. In the paper industry, the use of the device is so widepread that it seemed preferable to try to overcome the difficulties, retaining ne use of the Mullen tester, while in the leather industry it seemed

practicable to develop a better method with different apparatus. T
was found in a device having a cylindrical steel plunger with a hemispheri
tip, adaptable for use with a testing machine of 2,000 pounds capacity.

Multiaxially Stretched Plastic for Aircraft Canopies

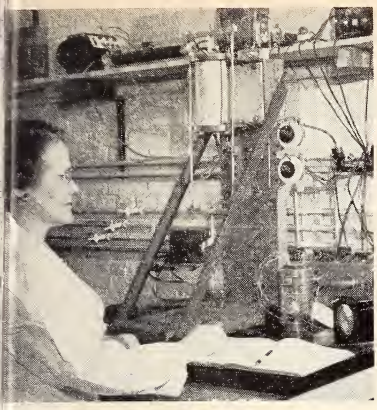
Transparent acrylic plastic is used for aircraft canopies rather than g
because it can more readily be formed to the streamlined shapes requi
and is lighter in weight. However, this material has a tendency to fo
tiny cracks or fissures. On some pressurized military airplanes a lamin
made of a soft vinyl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

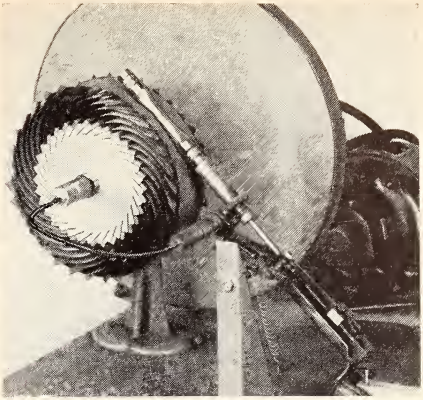
Recovery of Asbestos

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

9. Metallurgy

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





t: McKee Worker-Consistometer used at NBS to investigate the rheology of lber solutions, (p. 34). The device was originally developed at the Bureau to dy the effect of mechanical working on greases. Right: uniform polishing of tal fatigue test specimens (p. 41) is accomplished by using this polishing eel, consisting of a large number of metal spring leaves pressing against an asive belt.

rrosion

Studies of the corrosion of metals have been intensified because of the reasing awareness of the loss to the national economy from this source. rrent NBS efforts to reduce this loss include studies of the basic mecha-ms of corrosion, determinations of the relative merits of known materials resist corrosion in various environments, and evaluation of protective atings and protective devices.

Additional data were secured on the underground corrosion of metals om exposure sites maintained throughout the country; new theories of e mechanism of the corrosion of metals underground and of protection ainst this corrosion were developed; and experimental confirmation of the ore important of these theories was obtained. The theoretically derived lue of -0.85 volt for the cathodic protection of steel in underground rvice has been confirmed experimentally, and it has been demonstrated at the rate of corrosion of metals underground can be determined *in situ* thout disturbance. Studies were completed on the corrosion of galvan-ed iron and of low-alloy irons and steels after underground exposures up 17 years.

Stress-corrosion cracking, caused by the combined action of stress and rrosion, can be responsible for the spontaneous service failure of objects nging from brass cartridge cases to stainless-steel coffee urns. Although e problem is an important one, much remains to be learned about the echanism of stress-corrosion cracking. Corrosion is generally considered be an electrochemical phenomenon, involving the flow of minute electrical rrents between areas of different potential. When most metals are ex-osed to ordinary atmospheres, a thin oxide film is quickly formed that tends

to protect the metal from further corrosion. According to the most g
erally accepted theory, which the NBS study tends to confirm, stress-corro
cracking starts with a scratch or break in this protective film. When
protective film is broken through, the freshly exposed metal is more anc
(more negative) than the surrounding film-covered surface, and if moist
is present an electric current flows that causes the metal to be removed fr
the exposed area.

Deformation and Failure of Metals

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

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

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

Structure of Metals

Addition of small amounts of magnesium to cast iron has received i
creasing attention recently because it imparts desirable ductile qualiti
to the iron. It was shown during the year that the nodular graphi
produced by the action of magnesium on molten cast iron has the san
structure as the flake graphite normally found in cast iron. The improv
properties of the nodular iron therefore are due primarily to the sha

dy of the deformation and failure of metals at low temperatures resulted in findgs contrary to proposed theory (p. 40). A specimen submerged in a bath of uid air is being tested under a 50,000-pound-capacity testing head.

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

The solubility of chromium carbides in 18 chromium–10 nickel stains steel was shown to be much lower than was previously believed. This eans that only those steels that have been "stabilized" by titanium or lumbium can be relied upon for immunity to intergranular embrittlement der severe conditions of service.

etal Fatigue Tests

Several devices recently constructed at the National Bureau of Standards e proving valuable in speeding metal fatigue tests. The new auxiliary st equipment includes devices for stopping the testing machine when a nall crack forms in a specimen, apparatus for the uniform polishing of

fatigue test specimens, and a machine for fatigue-testing thin sheet sp mens in bending. Because metal fatigue, or fracture under fluctua stress, is the principal cause of service failure of machine parts, the la ratory study of fatigue of metals is of major importance. The continu fatigue studies at NBS rely largely on commercially available tes machines. Occasionally, however, it is found necessary to supplement th machines with specially-designed equipment such as the present new devi

10. Mineral Products

Research and development in the field of the nonmetallic inorganic n eral products is concerned with the determination of the constitution, str ture and physical properties of these minerals with a view to their m efficient utilization for defense purposes and for civilian use. Such produ include ceramic oxides, glass, refractories, porcelain enamels, building st concreting materials, lime and gypsum. During 1952 the Bureau conduc investigations pertinent to the development of atomic energy. The dev opment of refractories for jet engines continued, and improvements w made in ceramics with piezoelectric properties for special ordnance appli tions. The synthesis of useful silicates, especially asbestos, received incre ing attention. Detailed work on the structure of specific crystalline cc pounds of interest in cement technology proceeded satisfactorily. Progr was made in the development and standardization of test methods for cem and concrete. Pioneer work was undertaken in a study of the elastic a plastic properties of single crystals of ceramic oxides. Further progress v made in a study of the constitution of glass, especially with regard to t surface properties and phase relationships at high temperatures.

Refractory Concretes

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

stitution of Glass

Measurement of the physical and chemical properties of simple glass-ming systems is providing the experimental basis for a much needed theory he constitution of glass. For example, a recently completed study of the ses and liquids in the system $BaO–B_2O_3–SiO_2$ (of importance in the nufacture of optical glass) indicates by measurements of refractive indices l other properties that such glasses are not simple solutions of the oxides. new apparatus for the accurate measurement of index of refraction of s, simple in construction and obviating the use of ground and polished ples, has been developed as a byproduct of this study. The index of raction can be determined within ± 1 in the fifth decimal place with the v apparatus. One of the important uses of the instrument is in con-lling the index of refraction of optical glass: the sample can be prepared d measured in a few minutes.

nvestigations of properties of simple glass-forming systems have been ended to include alkali borates. The introduction of alkali oxides into ic acid is accompanied by strong attractive phenomena, shown by a ume contraction of the boric oxide. At low alkali oxide concentrations change of surface tension with temperature is roughly the same as that pure boric oxide. This is an indication of the strong attraction of the uid borate for the alkali. The attractive force varies inversely as the e of the alkali ion, the small lithium ion being pulled away from the sur-e more than the larger sodium or potassium ions.

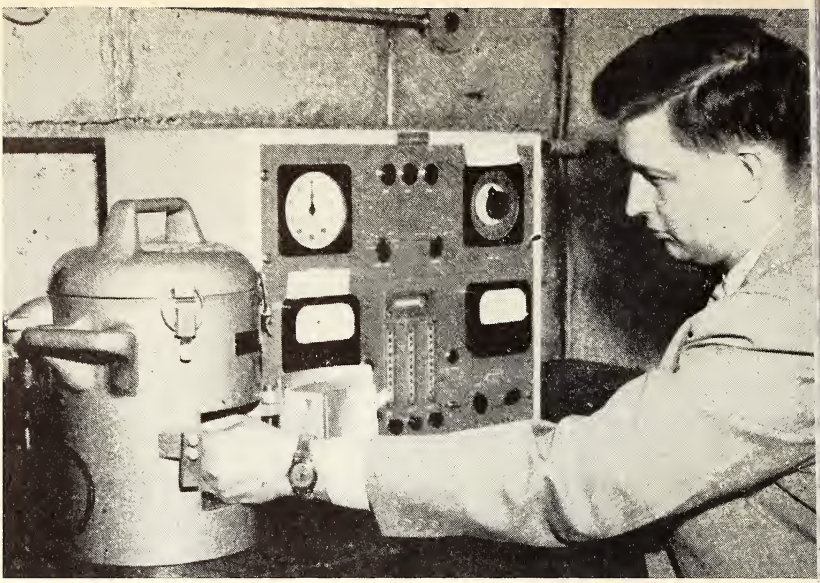
ramic Dielectrics

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

Life tests of direct-current volume resistivity of ceramics at 200°C reveal ceptionally good insulation properties of dielectrics made from calcium anate and from mixtures of titania with oxides of rare-earth elements, ch as neodymium and lanthanum. A resistivity of more than 10^{10} ohm-cm as maintained by these ceramics at 200°C during the schedule in which increase of 5 volts per mil was made at 7-day intervals for the range of to 30 volts per mil. This behavior necessitates a modification in the con-pt currently held that all titanates have poor insulation properties when bjected to 5 volts per mil or more at elevated temperatures.

eramics for Atomic Energy

Refractory ceramics with favorable nuclear properties are of interest to the tomic Energy Commission for a great variety of high temperature applica-



Radioactive cobalt is used as a tracer to study the adherence of porcelain ename steel (p. 45). The specimen is placed in "lead pig" (left), which contain Geiger-Müller tube. Radioactivity detected by the tube is counted on sc (center).

tions. Fundamental data concerning the thermal stability, compatibil and other properties are being obtained for oxides, metals, and carbides importance in this connection. For this work a special inductively-hea furnace and a metal-resistance furnace were designed and construct Specimens may be heated in these furnaces at very low absolute atmosphe pressures (as low as 5×10^{-5} mm of mercury at the beginning of a test) or a neutral gas in which oxygen is believed to make up less than 1 part in th million. The behavior of these materials in combinations, when heated temperatures between 800° and 2,500°C, is being evaluated by means X-ray diffraction techniques, chemical analysis, visual observation, and t study of their microstructure. For example, the fundamental phase eq libria have been investigated for four binary systems—UO_2-Al_2O_3, UO_2-Be UO_2-MgO, and UO_2-SiO_2.

Ceramic Coatings for Electrical Uses

Specialized ceramic coatings were developed to replace a scarce grade mica in electronic components. Investigation revealed that unconvention alkali-free coatings were superior to commercial-type porcelain enam when electrical insulation at elevated temperatures was required. Sim lated service tests of ordnance components indicated that several of t developed coatings could successfully replace mica for the intend application.

erence of Porcelain Enamels

n effective ceramic or porcelain-enamel coating must adhere to the al it is designed to protect. Cobalt oxide effectively promotes adnce of porcelain enamel to iron, and for this reason has long been ed to enamel ground (first) coats. Despite a great deal of research, vever, the mechanisms by which cobalt oxide promotes adherence are not l understood. Consequently the fundamental study of adherence of celain enamel ground coats to iron, sponsored by the National Advisory mmittee for Aeronautics, was continued throughout the year. An inigation of the correlation between roughness of interface and adherence ween a cobalt-bearing porcelain enamel ground coat and iron revealed t roughness of interface is a necessary but not sufficient condition for the elopment of good adherence. Further studies proved that the roughs contributing to adherence is produced during firing by selective corion of the iron and solution of iron oxide in the enamel. This selective rosion was attributed to galvanic currents developed on contact between iron and metallic cobalt deposited from the enamel at the enamel-metal erface. Previous experiments with radioactive cobalt had shown that tallic cobalt is precipitated from the enamel and deposited on the iron ring firing. Other experiments showed that galvanic corrosion can and es occur in an electrolyte of molten enamel during the short firing period. ese data provided experimental evidence for support of the galvanic ory of adherence.

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

hermochemistry of Mineral Products

Because of their favorable effects on the properties of concrete, pozzolans ntaining active silica are added to portland cement. There is a need

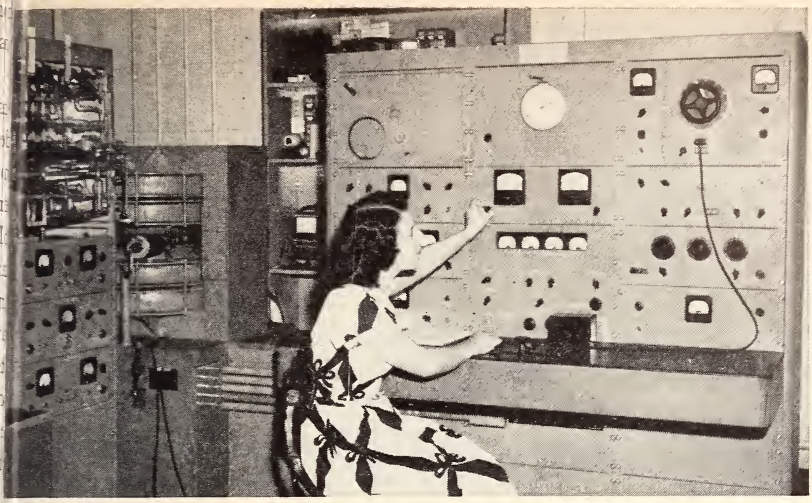
for methods of test of portland-pozzolan cement to determine the am of pozzolan which has been added as well as to determine the hea hydration of the product. The silica renders the blended cement partially soluble in the calorimeter acid used in determining the hea solution of portland cement. Techniques have been devised for d mining the heat of partial solution of portland-pozzolan cements an hardened pastes, which permit the measurement of the heat of harde of the blended cement. The fraction of the pozzolan which is insolub the calorimeter acid is relatively constant. The percentage of pozzola the blended cement can therefore be estimated from the weight of un solved material remaining in the calorimeter at the end of the hea solution determination. Measurements were made of the heat hardening of mixtures related in composition to the magnesium oxychlo cements. It was found that, per gram of MgO, the heats of harde of all the mixtures were nearly the same and that about 80 percent of total heat of hydration was evolved in the first 24 hours after mixing.

Cement

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

11. Building Technology

The need for economy in the construction, operation, and maintena of buildings has been the reason in recent years for the National Bur of Standards to undertake a critical examination of old practices an search for new practices based upon sound engineering principles. Be full advantage can be taken of the kind of engineering approach that guided the rapid technological development of the electrical, automo and aircraft industries, the building profession must be supplied with curate standards of measurement, new testing procedures, fundamental gineering data and fundamental performance standards. No indust organization has the facilities to obtain the needed fundamental enginee data. The building profession, therefore, depends on the National Bur of Standards as the principal laboratory of the Government for basic resea in the fields of building materials, structures and equipment (exclud forest products which are studied by the Department of Agriculture Fo Products Laboratory). In addition, the armed services call on the Bur



analysis mass spectrometer used to determine the evolution of gases in vitreous ings on steel (p. 45).

develop testing methods and to obtain technical information which are mmediate value to them.

The fields of interest to the Bureau are those of structural engineering, lding codes, safety engineering, fire protection, heating and air-condi- ning, and wall, floor, and roofing materials. Typical studies underway lude resistance of concrete to impact, problems of the cracking of sonry, studies of the mechanism of fire-spread, performance evaluations various types of heating systems, measurement of the heat-transfer prop- ies of building materials, evaluation of air-conditioning and refrigeration uipment, and development and evaluation of asphaltic materials, floor faces, and bituminous roofing. Assistance to federal, state, and munici- l bodies on the development of adequate building codes and to industry d the Federal Government on the development of safety standards is ntinuing.

ermal Conductivity

Measurements of the thermal conductivity of homogeneous materials used building structures have been carried out for several years in the Bureau's arded hot-plate apparatus. Evaluation of the thermal conductance of alls, floors, and roofs containing air spaces represents a special problem, in at the heat flow depends on the size of the specimen and its orientation: ot only must large-scale test specimens be used, but arrangements must be ade to allow rotation of the specimen around a horizontal axis, so that the nductance may be measured when the heat flow is horizontal, vertically ward, or vertically downward. To effect this, the Bureau developed the tatable hot-box apparatus, in which specimens 5 by 8 feet in size could tested. Building elements of various types have been tested in the rotat-

able hot box, including those with highly-reflective air spaces such as alu num surfaces, those with non-reflective air spaces, including surfaces pai with black asphalt paint, and those with air spaces of intermediate flectivity such as silvercote insulation. Total radiation emissivity has b measured, thermal conductances obtained for various surface emissivi and a generalized relationship obtained to correlate the variables. results should make possible the evaluation of the thermal-insulating q ities of constructions, insulations, and paints used in floors, walls, and ro

Resistance of Floor Coverings

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

Cellular Concrete

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

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

ective Coatings for Concrete Masonry

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

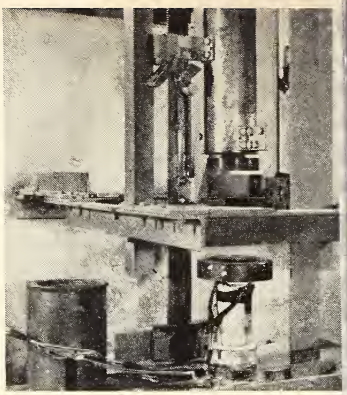
ndow Air-Conditioning Units

The Bureau has undertaken a variety of projects concerned with the luation of refrigeration and air-conditioning apparatus. Typical of se is the evaluation of several commercial ¾-hp window air-conditioning ts for the Department of the Army. A portable, 150-cubic-foot ware- use normally used for refrigerated storage served as a calorimeter. The cooling capacity of each of the units was determined for various com- ations of indoor and outdoor temperature, up to an outside temperature 125° F. Air-circulating capacity of the evaporator and condenser fans s measured and a determination of the maximum quantity of ventilating introduced by the unit into the conditioned space through the fresh-air mper was made. The electrical circuitry, including motor-overload otective devices, was tested under severe conditions.

diant Glass Heating Panels

Electrically powered radiant glass heating panels have been evaluated der various conditions of use in the NBS Test Bungalow. The tests, ade with outdoor temperatures ranging from 0° to 32° F, showed that e vertical temperature differences in the living zone were moderately w, comparing favorably with most other systems previously tested. The rtical temperature variation was found to be essentially unaffected by e presence or absence of insulation in the walls and storm windows. ne average horizontal temperature variation between rooms was 2.5° F less for all observations.

Comparisons were made with forced warm-air heating using identical tdoor temperatures and with indoor temperatures maintained the same



Left: resistance of various floor coverings to effects of grease, oils, alkalis, and a is determined by scratching exposed specimens with sharp tool (under the gram mark). Width of the scratch gives measure of resistance of various cover to different reagents (p. 48). Right: concrete cylinder (bottom center) set up impact testing with drop hammer (p. 48).

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

12. Applied Mathematics

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

Numerical Analysis

The study of large sets of simultaneous algebraic equations and techniques for the inversion and iteration of matrices has been called t

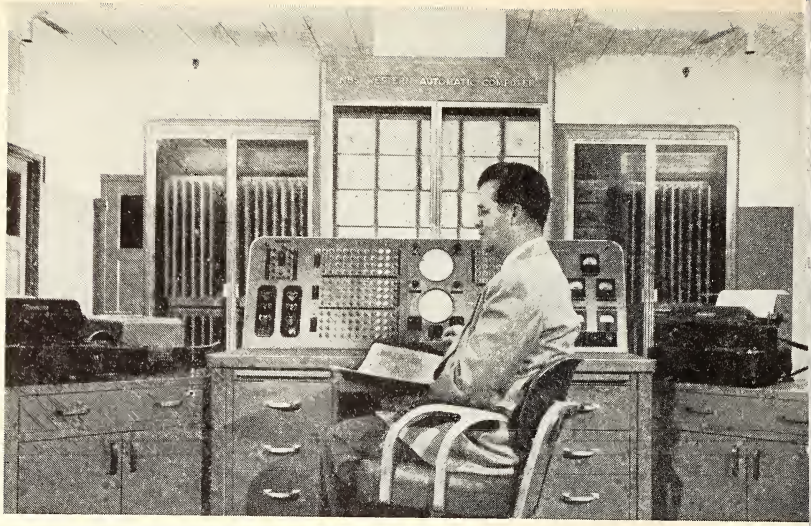
problem of numerical mathematics. The Method of Conjugate dients was investigated and appears to be a most attractive method finding the eigenvalues of a matrix. During the year experimental putations were undertaken in order to test the stability of the method egards round-off errors and related problems. Studies of the numerical gration of differential equations were continued. This subject is im- ant because of the large number of applied problems which are hematically formulated in this manner. The Bureau is accumulating arge body of information concerning the feasibility of solving such blems by means of large-scale computing machinery.

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

A number of computational experiments on this and on other problems s carried out. The goal of such investigations is to find practical putational methods utilizing high-speed computing equipment. As a product of the program, the primality of Mersenne numbers was in- tigated and toward the end of the year a new prime, $2^{1279}-1$, was dis- ered. This, the fifteenth perfect number, is by far the largest prime covered to date.

tistical Engineering

The program in statistical engineering is concerned with the application modern statistical inference to complex engineering experiments and npling problems and with the analysis of data arising in physical experi- nts. Advances in the field of experiment design have for the most part en stimulated by the needs of experimenters in agriculture and biology. perimental arrangements that are successful in these fields often e not applicable in the physical sciences. The NBS has thus developed o new classes of experimental arrangements to meet needs of physical entists, and these arrangements have found application in experimental ograms in spectroscopy and temperature measurement at the Bureau. Work on stochastic processes and on the theory of extreme values was rried out. The Bureau is now engaged in preparing a bibliography and ide to statistical methodology literature. Basic research has been under- ken on distribution-free methods of statistical analysis and on properties characteristic functions. Perhaps the most important of the theoretical udies being carried on by the Bureau is that relating to the development of theory of measurement. This research is basic to studies of the accuracy id precision of measurement processes and is directly related to activities other sections of the Bureau concerned with establishment and mainte- nance of basic standards.



SWAC operated on a 40-hour week (p. 65).

Computation

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

Essential contributions to the success of Atomic Energy Commission p grams were made. Computations required in many other military proble were handled, such as trajectories of various missiles, design of fire-cont equipment, and studies of explosions. Major contributions were also ma in connection with work for the Office of the Air Comptroller. Programs the deployment of aircraft of various types were computed, so that there n be a proper balance between various activities of combat, reserve, and tra ing. In this connection, computations concerning a model of the natio economy, the so-called Emergency Model, have been completed. The co putation of Loran navigation tables was transferred to SEAC, at a cons erable saving in time compared to the manual and punched-card computi methods previously used.

13. Electronics

In electronics the Bureau carries out a broad and diversified progra including both research and development. Research is directed towa

ain basic phenomena and properties of materials of potential signifi-
e to electronics. Development covers not only the field of electronic
uitry for the performance of new functions by electronic means but also
broader phases of fabrication technology by which optimum engineering
gns for electronic equipments may be achieved. Emphasis has also been
ed on the improvement of operational reliability of electronic equip-
t by the development of new components and the application of new
erials and improved assembly techniques. This work is of particular
ortance to the military in the adaptation of electronic devices to extremes
limatic and operational surroundings. Much of the work is sponsored
he Department of Defense as well as by other Government agencies.

During the past year, the work in electronics consisted essentially of an
ansion and intensification of the various phases of the program already
ler way, including new components and new techniques; the publication
a report providing complete information on the preparation and prop-
es of the NBS Adhesive Tape Resistor over a range of resistances from
ohms to 10 megohms; investigation of possible methods for prediction
ailure in electronic equipment; investigation of the functional behavior
cathodes and gases in electron tubes; development of testing evaluation
cedures and test equipment for electron tubes; development of special-
pose electron tubes; development of an improved cuvette recording
nsitometer; the publication of a complete final report covering four in-
umentation systems for the measuring of oil film thickness in journal
rings; the development of a vibration calibration instrument covering
e range of 10 microinches to 10 mils over a frequency range of 20 to
,000 cycles per second.

An increasing amount of technical attention was directed toward appli-
tion engineering, particularly in the introduction to service of new
uipment already developed by the Bureau. Examples of such work
clude the automatic currency counting equipment developed for the
reau of the Public Debt, Department of Treasury, and the automatic
mperature monitor and the turbine rotor position indicators developed
r the Bureau of Ships, Department of the Navy.

dhesive Tape Resistor

Printed electronic circuits—in which components and wiring are super-
posed directly on insulating bases—are being used increasingly because
ey are adaptable to mass production and facilitate miniaturization of
uipment. The major disadvantage, however, has been the difficulty of
corporating satisfactory resistors in the circuits. This difficulty was
rgely overcome in 1951 by development of an adhesive tape resistor
ethod, sponsored by the Navy Bureau of Aeronautics.

In this technique, circuits are first printed in narrow metallic bands on
nsulating bases, leaving a small gap at each point where a resistance is
quired; one of the self-adhesive resistors is then cut from a strip and pressed

Instrument for detecting incipient failures of electronic equipment (p. 55)

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

Miniaturization

Under sponsorship of the Navy Bureau of Aeronautics, the Bure continued the development of techniques applicable to the subminiaturiz tion of military airborne electronic equipment. Because of the importan and wide usage of air-to-ground communication from 220 to 400 Mc, ar because of the unusual problems peculiar to those frequencies, miniatu zation of an airborne transmitter-receiver in that range presents a difficu task. Design and construction of such a transmitter-receiver was progress during 1952. The set will have no dimension larger than 24 inch

will be made up of individual plug-in assemblies. Also carried out ng the year was the redesign and miniaturization of an airborne radar which has been selected by the Navy as standard equipment for a new of aircraft.

tronic Failure Prediction

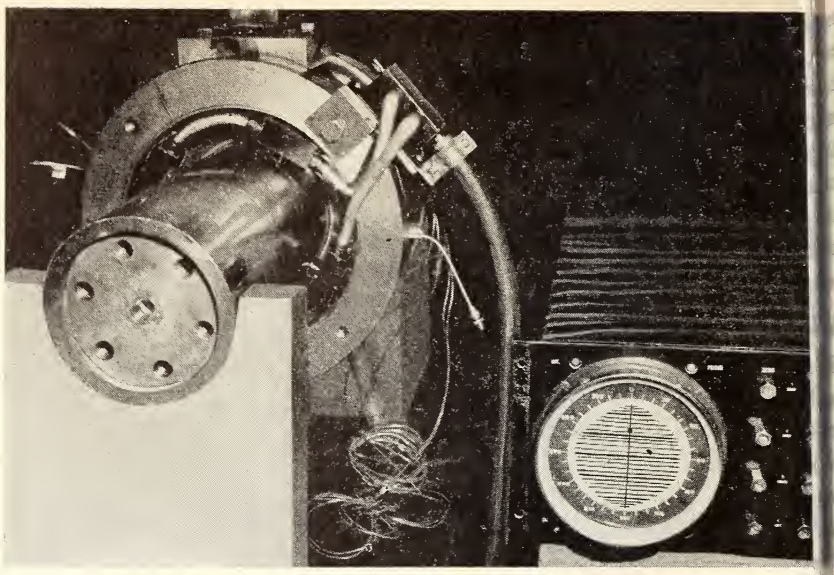
ince most types of electronic equipment failure are preceded by gradual rioration, the possibility exists that these deteriorations can be detected predicted. Under sponsorship of the Office of Naval Research, the eau has undertaken to develop equipment along this line. For ship- ne or land equipment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

vette Densitometer

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

l Film Thickness Indicators

In studies of engines and engine lubricants, it is often desirable to measure arances between shafts and sleeve- or journal-type bearings during opera- n. It is usually difficult to obtain such measurements without affecting e operation, particularly at high speeds. A method developed at the NBS r the Navy Bureau of Ships offers a satisfactory solution of the problem. ne heart of the new system is a mutual-inductance type of electrical dis- nce-measuring element; variation of the distance of the rotating shaft om two small fixed coils results in a readily measurable variation in the upling between the coils. Three successful variations of the device were veloped. The models differ in the type and number of probes used, in nsitivity, in suitability for measuring vibratory conditions, and in type of dicating device. A cathode-ray tube is used with one model to provide a



Probes of oil film thickness indicator (p. 55) are mounted at shaft entranc sleeve-type bearing. Cathode-ray tube (dial face) gives clearance between the s and the bearing. (Photo courtesy of U. S. Department of the Navy.)

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

Steam Turbine Rotor Position Indicator

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

Vibration Calibrator

The Navy Bureau of Ships desired an instrumentation system to assist calibrating simple vibration pickups, thereby eliminating the tedious ta of individual calibration of each pickup. At the same time, it has be difficult to find standards for measuring high-frequency vibrations when t components are under test for such characteristics as noise, microphoni

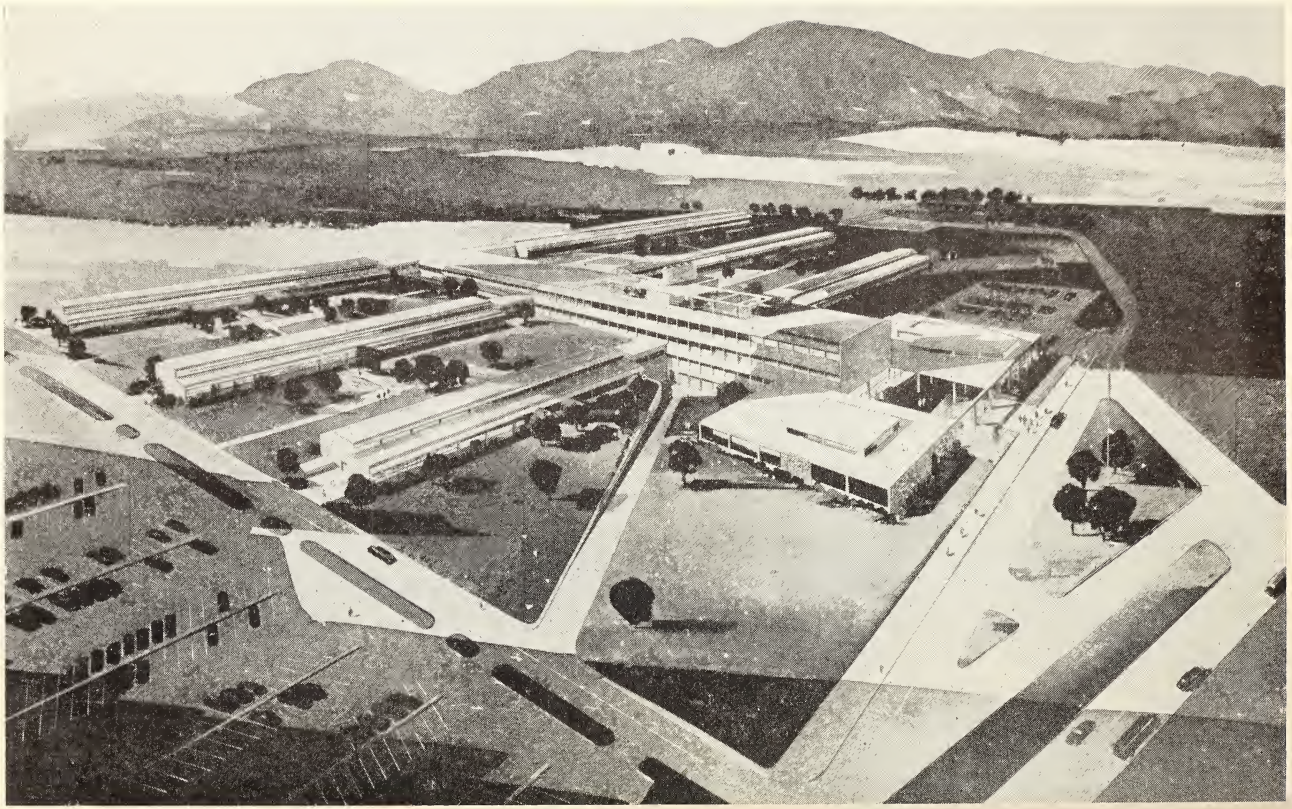
tability. To provide a suitable method for both of these fields of measment, an instrument based on mutual-inductance micrometer techniques developed by NBS for the calibration of vibration pickups. The inment measures vibrations in the amplitude range of 0.00001 inch to inch over a frequency range of 20 to 10,000 cycles per second and with accuracy of 5%. The equipment is composed of two units, the probe t and the electronic chassis. The probe, less than one inch in diameter, tains the mutual-inductance transducer. Provision is made for obsertion of the waveform on a cathode-ray oscilloscope.

ble Gas Clean-Up in Electron Tubes

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

14. Radio Propagation

The National Bureau of Standards Central Radio Propagation Laboratory serves as the primary agency of the Government for research in radio ave propagation and for the centralization and coordination of informaon in this field. The laboratory is also responsible for the development d custody of the national primary standards for electrical quantities at dio frequencies. Comprehensive programs are undertaken in radio physics d associated geophysical phenomena of the upper atmosphere and the oposphere. Extensive laboratory studies are also under way dealing with roperties of matter at radio and microwave frequencies and the development of techniques for precise measurement of electric quantities in this gion. In addition to such research activities, the Bureau does a large mount of advisory and consulting work on radio for other agencies of the overnment such as the Department of Defense, the Civil Aeronautics Adinistration, and the Federal Communications Commission, and particiates in an advisory capacity to the State Department in the international



Architect's drawing of new laboratory to be used for radio propagation research, now under construction at Boulder, Colorado

io conferences. The work in radio propagation is divided into four nches: ionospheric research, regular propagation services, systems re- rch, and measurement standards.

The Ionospheric Research Laboratory conducts basic research on the ture of the upper atmosphere and its ability to reflect radio waves. The reau uses a widely separated network of 17 ionospheric sounding stations tending over the American continents and the Pacific area. Data sup- ed by these observatories provide basic material for research and for de- mining frequencies to be used in long-distance radio communication. addition, a permanent radio propagation field station at Sterling, Va., d a number of temporary field stations are operated for performance of ecial experiments. Because of the important influence of extraterrestrial fects on ionospheric phenomena, solar and cosmic phenomena are studied. nese include radio waves emitted by the sun and other celestial bodies, nich also afford a new means for exploration of the universe.

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

The Systems Research Laboratory applies radio propagation informa- on to the practical problems of radio communication with particular con- deration to the advantages and limitations of the types of communication stems involved. It also conducts research on the propagation aspects of arious radio systems such as FM and TV, on radio noise, types of modula- on systems, and practical improvements of radio predictions and radio avigation systems.

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

Radio Astronomy

Cosmic and solar radio waves reaching the earth from outer space limit he minimum usable signal levels for FM broadcasting, television, and ommunication and radio navigation services in the very-high-frequency ange. In recent years, the techniques of radio astronomy have been de- eloped for receiving and analyzing these radiations from outer space. This

had made it possible to obtain information about the positions of ste bodies and the matter in interstellar space that could not be obtained v an optical telescope.

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

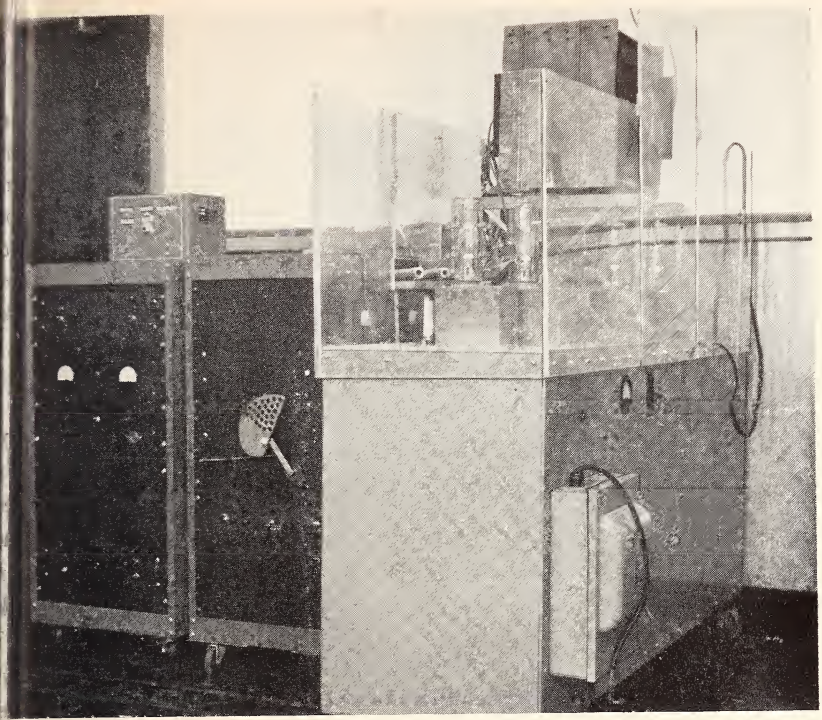
Ionospheric Winds

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

Low-Frequency Ionosphere Recorder

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

The recorder furnished daylight information about the E layer nev before available. A remarkable phenomenon noted on continuous motio picture records of repeated sweeps was the formation of the regular layer at sunrise. It appeared to grow out of the night F2 layer, droppi in virtual height and developing a cusp within a period of four minut Details of the F2 extraordinary reflections at frequencies below the gyr frequency were visible as were details of certain types of stratification.



nsmitter assembly of new ¾-million-watt low-frequency ionosphere recorder 60). Power supply (left), low level amplifiers and pulse generator (middle), l amplifier (right).

dio Navigation

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

odulation Studies

Because of the scarcity of space in the radio-frequency spectrum and the cessity for more reliable communications, a study of the efficiency of rious types of modulation and methods of communicating over radio ths has been undertaken. The frequency spectra, including phase infor- ation, were obtained for a large number of modulating wave forms ap- ied as amplitude, frequency, or multiple modulation to a carrier fre- uency. The bandwidths necessary for satisfactory system operation were

obtained for some specific systems, such as frequency shift keying. In
tion, simplified formulas were derived for the interference produced
number of waveforms employed in both AM and FM systems. Sp
formulas were derived for the interference bandwidth at any specified
for frequency shift teletype, frequency shift facsimile, and sub-carrie
quency shift facsimile. Other work includes a review of the condi
necessary for high-frequency broadcast reception and the derivation
formula for calculating the noise figure of an FM receiver or the mini
satisfactory input carrier for a given output signal-to-noise ratio.

New laboratory facilities were established for the modulation studie
linear modulator which is capable of simultaneous or independent ar
tude and frequency modulation was constructed. Initial operation o
equipment in conjunction with a panoramic analyzer showed good a
ment with the spectrum calculations. A pulse generator capable of
erating arbitrary pulse forms of finite length was completed for use in st
ing optimum pulse shapes and filter shapes for various applications.

VHF Propagation Research

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

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

Terrain Effects on VHF Propagation

In cooperation with the United States Army Signal Corps, a mobile ra
field-strength laboratory was used to study the directivity of directic
antennas over irregular terrain, at frequencies from 49 to 460
Throughout the frequency range it was found that considerable variat
in apparent antenna radiation pattern existed due to variations in
configuration in the intervening terrain. Theoretical studies were mad
determine optimum frequencies for short-distance communications us
low-powered portable equipment over irregular terrain paths.

r Standards

improved calorimeter for the precise, absolute measurement of micro- power was designed and constructed. This instrument measures owave power at frequencies in the neighborhood of 9000 Mc at a of a few milliwatts. The techniques are not intended to supplant entional microwave power-measuring methods but rather to enable rate calibration of secondary power-standards of various types. The ned accuracy of better than one percent appears more than adequate nost present-day requirements.

edance Measurements and Standards

urther work was done on the development of impedance standards, in- ing several types of impedance standards for waveguides. These stand- erminations to waveguides or coaxial lines have known reflection prop- s and are very useful in the microwave laboratory. One type consists n accurately matched and calibrated attenuator terminated by a short- plate. Designs for waveguide discontinuities that are amenable to pre- mechanical construction and to theoretical calculation were selected, calculations were partly completed.

technique for combining known waveguide impedances by means of eguide junctions to produce new known impedances was investigated er thoroughly for the case of H-plane T-junctions. Comparison tech- ues, enabling comparison of unknown with known impedances which "magic-T" junctions, were developed to a point considered adequate the present. The resonant-line (Chipman) technique of impedance surement was studied in both coaxial and waveguide versions.

io Interference and Noise Measurement

program was initiated which, if successful, will lead to the establish- t of a complete calibration service at NBS for radio interference meters, uding those employing rod-type antennas. The design and construction detector to determine the rms, peak, and quasipeak, or average value he interference over any time interval up to several seconds were com- ed. Preliminary investigation indicated the problem of interference er standardization to be both urgent and of very large proportions. luation of a standard noise source usable up to 4.2 Mc was completed n very good agreement (better than 0.5%) between experimental and oretical constants. Work was under way on sources usable up to 30 Mc.

mic Standards of Frequency and Time

ecause of fluctuations and secular changes in the length of the solar , unchanging standards of frequency and time are needed by science. ce the first atomic clock, based on the constant natural frequency asso- ted with the vibration of atoms in the ammonia molecule, was announced NBS in 1949, an intensified program has been carried on which now

comprises the investigation of four different types of atomic clocks. S
trum lines which are both very intense and sharp are required in this
to secure an ultimate standard. One of the most troublesome prol
found in the ammonia clock has been a Doppler broadening of the spec
line, and much study has been devoted to the possible kinds of spec
lines that could be best employed, the atomic systems involved in obta
such spectrum lines, and the methods of excitation of these systems.

The most promising results have been obtained so far through the u
magnetic resonance techniques employing atomic beams. The work or
method (considered to have the highest potential accuracy) was b
shortly after the initial work on the ammonia clock. The equipmen
now been completed and preliminary work done on the excitation o
spectrum line in an atomic beam using cesium. With this equipme
spectrum line having the sharpest resonance ever obtained has been exc
The measurements have furnished direct evidence indicating the possil
of measurements to better than a part in 10 billion—an accuracy co
erably greater than that achieved in the measurement of optical waveler
and about 100 times greater than present astronomical frequency and
standards.

15. Automatic Electronic Computers; Information Processi

SEAC

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

In its role as an experimental tool, SEAC has been used to test impro
input-output devices and memory units. A magnetic tape device has b
developed which permits rapid starting and stopping of the tape by elimi
ing the inertia associated with ordinary reels. In this device the tap
stored in loose folds in a two-dimensional bin. To start the tape it is c
necessary to accelerate a few feet of the tape material itself, and not
entire reel. These devices have been tested and have been put into regu
operation in problem solutions. Because of the bulk of the bins in wh
the magnetic tape is stored, these units are not readily adaptable to load
and unloading with ease. A separate unit has been developed which ma
use of spools of magnetic wire assembled into a plug-in cartridge. T
cartridge does not permit the rapid accelerations of the reel-less magn

units, but it is much more rapid and convenient for loading and un-
ng. It permits a new problem to be inserted into the machine in a
er of a few seconds, and results may be removed equally rapidly. Equip-
also has been constructed and is in regular use which takes results
ded on this magnetic wire and prepares, independently of the central
hine, a printed copy for punched cards.

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

AC

ver 600 hours of useful computing time was obtained on SWAC (Na-
al Bureau of Standards Western Automatic Computer), and the useful
rational rate by the end of the year was approximately 40 hours per
k. A punched-card input was installed, permitting the memory to be
led in 6 seconds in contrast to the 5 minutes required by teletype tape.
number of studies in pure mathematics were carried out using SWAC.
example, the primality of Mersenne numbers was investigated, and
ard the end of the year a new prime, $2^{1279}-1$, was discovered. This is
largest prime number discovered in mathematics. (See page 65).

w Computers

he first new computer is the STATAC-SCOOP, which is a serio-parallel
chine of very high speed, being designed for use with a parallel electro-
ic memory and intended primarily for application to large-scale com-
ing problems such as the SCOOP project of the Office of Air Comp-
ller, USAF. Since actual construction is dependent on realization of a
h-performance parallel electrostatic memory, the major effort has been
oted to continuation of the analysis relating to the so-called triangular
del type operations. Many of the equipment design features are being
ed out in the construction of DYSEAC, particularly the new package
nstruction.

The second new computer, DYSEAC, is a full-scale general-purpose
ial machine operating at a 1-megacycle repetition rate and containing
erial acoustic delay-line memory of at least 500 words. It differs from
AC in the following particulars: (1) it contains an expanded repertoire
arithmetic operations; (2) it contains provisions for annexing a greater
riety of external storage and input-output devices; and (3) it is capable

SEAC operates on a 24-hour day, 7 days a week (p. 64). New reel-less magn tape external memory devices (right and center) which have unusually fast a time (p. 64). Insert: for loading and unloading the computer very rap magnetic wire cartridges were installed (p. 64).

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

Technical Services

The Bureau also acts in an advisory and consulting capacity for ot Government agencies interested in acquiring automatic computers. Du 1952 the Bureau accepted two computers and monitored their installat One was delivered to the Office of Air Comptroller, the other to the Ar

Service. Computer design and procurement for the Air Force Missile Center and Willow Run Research Center (University of Michigan) continued as cooperative efforts. The Bureau is also technical representative for the Bureau of the Census, which operates a data processing chine. The Bureau has continued to serve as a clearing house for information on the potential applications of electronic digital-computer techues both for scientific problems and for the processing of business types ata. NBS representatives have met with officials of many Government ncies and industry.

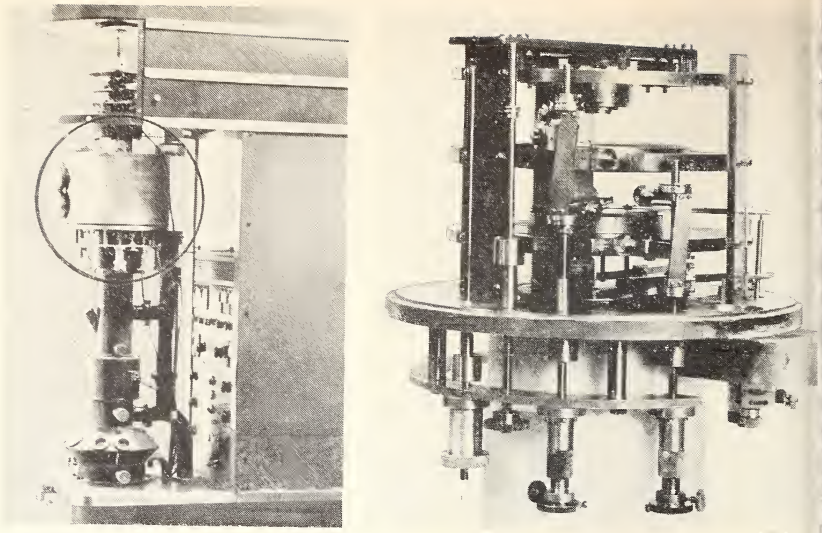
rmation Storage

he storage of information on punchcards, film, magnetic wire and tape come into wide use in the last ten years. A basic problem in such storage ems is the speed with which the stored information can be selected. Anrs to this and other problems, such as the reduction in size of the equipnt and the storage medium, are being sought by the Bureau. Part of the k is related to the NBS program on electronic computers, and some work eing done to solve particular problems for other government agencies. A special paper punch is being completed for use in connection with the pid Microfilm Selector now located in the library of the Department of riculture. This punch will make it possible for an operator to prepare cial perforated cards by merely pushing keys similar to those on adding chines. In addition, a light-box is being provided on which these cards to be mounted for photographing numerical subject codes alongside the crofilm image of a page of printed matter. This is the second part of an provement program in connection with the Rapid Microfilm Selector. A punchcard-sorting machine, which operates on an entirely new prinle, is being completed for the Census Bureau. In this machine the cards e carried by an endless belt. Each card is accompanied by a set of twosition cams which can be arranged to designate a pocket into which the d is to fall. This makes possible the construction of punchcard-sorting achines with unlimited numbers of pockets. Present sorting machines are nited to about 40 pockets at the very most.

A Notched-Disc Memory Device developed by the Bureau is in process of nstruction by a contractor. This model will be able to store about as uch information as a quarter million conventional punchcards, even ough it is only a one-quadrant model. A full-circle machine could handle ur times this information. Access to any part of the stored information quires only a small fraction of a second.

16. Basic Instrumentation

Since its founding, the National Bureau of Standards has carried on a rge amount of research in instrumentation. However, in order to take full dvantage of the Bureau's facilities and competence in the general field of hysical measurements and to bring into play the ideas and developments



Left: electron interferometer (circled) installed between the electron gun and objective lens of a conventional electron microscope. Right: close-up of electron interferometer (p. 68).

originating in all technical fields, a coordinated program of broad scope w needed. The NBS Office of Basic Instrumentation was established in 19 for this purpose, with the cooperation of the Department of Defense and t Atomic Energy Commission. Functions include general correlation of B reau projects in basic instrumentation, maintenance of liaison with sponsc ing agencies, arranging for cooperative work on special problems, continu survey of instrumentation work in progress at NBS laboratories, arrangi for the testing and evaluation of new instrument developments, and stimul ing theoretical and experimental studies of original ideas for improved novel means of measurement. Because instrumentation cuts across all lin of technical activity and the specific projects under the general program a carried on in many of the existing divisions of the Bureau, the Office Basic Instrumentation was established as a part of the Director's Offic The following projects represent some of the efforts of this office.

Electron Interferometer

The concept of using lamellar crystals for splitting an electron beam su gested the possibility of this instrument. Theoretical and design studies co firmed the soundness of the proposed method, and an instrument has bee constructed.

This instrument, an analogue to the classical optical interferometer, expected to throw new light on the nature of the electron by providing means of measuring the length of the wave train that modern theory assoc ates with an electron. This knowledge can also be expected to give rise t a better understanding of the process of electron emission, the phenomen on which all of electronics is based. Moreover, since electrons of an energ

monly used in electron optics have a wavelength one ten-thousandth of t of visible light, an electron interferometer provides a basis for the asurement of length down to atomic dimensions.

ise-Free Instrument Cable

purious electrical signals or "noise voltages" present a problem in many es of instrumentation work where instrument cables are subjected to chanical forces. They interfere with measurements of pressure in under- er explosion and air-blast research and with determination of accelera- n in shock and vibration studies. They also adversely affect the perform- e of crystal-type microphones, hearing aids, and phonograph pickups d many other high-impedance devices in the fields of communication, asurement, and control. Until now, the mechanism of the noise genera- n has not been well understood and has been assumed to be somehow ated to piezoelectric or converse electrostrictive effects, changes in the ctrical constants of the cable, or separation of electrical charges by ction.

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

agnetostriction Magnetometer

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

ulsed-Voltage Photomultiplier

Study of such light-emitting phenomena as those connected with single uclear disintegrations require light-sensitive elements having resolving imes of the order of 1 millimicrosecond. Ordinary techniques using photo- lectric cells are not capable of this resolution. Efforts to improve the per- ormance of photomultiplier tubes have resulted in the development of echniques for intermittent tube operation in which relatively high tube

voltages and currents are used, with a resulting increase in tube performa greater than an order of magnitude. Experimental work presently unc way, in which radio frequency voltages are applied to the tube elemer shows promise of equal improvement, with substantial simplification equipment.

Mutual Inductance Transducer

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

17. Calibration, Testing and Standard Samples

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

The NBS calibration service is of great benefit to industry and priva laboratories. Thousands of instruments are yearly sent to the Bureau f calibration. Some of these are standard laboratory devices and some a master instruments used by industry to calibrate production tools. Standa samples are materials that are certified for chemical composition or for son physical or chemical property, such as heat of combustion, melting point, index of refraction. Standard samples of steels help to control the quali of the steel industry's output. Primary chemical standards and metals wit certified melting points make possible uniform measurements of heat an temperature in the same way that standard weights provide uniformity measure in buying and selling. Standard pigments define the colors c paints. A large variety of hydrocarbons, supplied as single substances c high purity, calibrate the instruments that control the composition of moto gasolines, aviation fuels, and synthetic rubber. The list of standard sample issued by NBS now includes about 500 materials.

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

During the year over 300,000 tests and calibrations were performed fo other Government agencies and the public. In addition, about 33,00

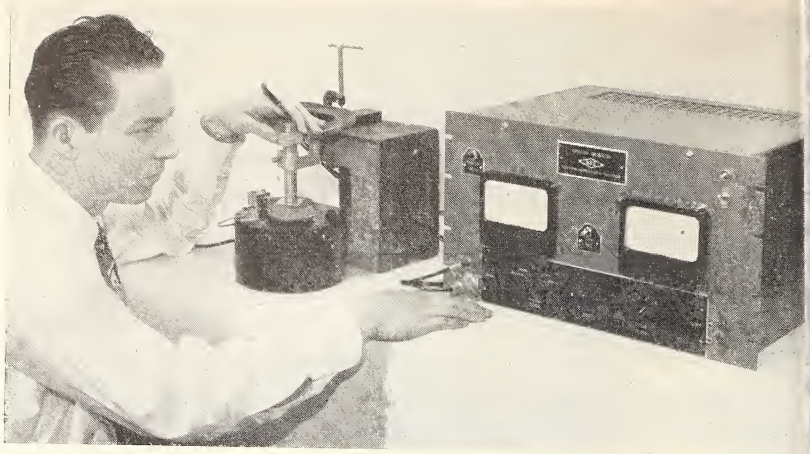
ard samples were prepared and distributed. Typical services of this included the sample-testing of over 200,000 clinical thermometers pur- d by the Government, the life-testing of about 4,500 light bulbs (a sam- of nearly 7,000,000 purchased by the Government this year), the cali- on of approximately 8,900 gage blocks, over 860 measurements of radon ath samples, the testing of 277 ores and sludges for radium content, the ation of more than 700 water-current meters, and the calibration of 0 capacity-measuring devices.

ore than 15,800,000 barrels of cement were sample-tested during the The increase of approximately 3,300,000 barrels over the previous was largely due to increased Federal construction. The tests, consisting ysical and chemical analyses, were carried out at four separate field ns established for this purpose as well as at the central laboratory in hington. Closely related to this work is the program of the Cement rence Laboratory, which inspects the apparatus and test methods of nt-testing laboratories. This laboratory is located at NBS and is jointly orted by the Government and the American Society for Testing Mate- . The Public Roads Administration contributes to the financial sup- of the project and requires that laboratories testing cement for Federal- projects must be inspected regularly by the Reference Laboratory.

or many years, all radium preparations sold in the United States have n tested and certified by the Bureau. During the year 1,808 tests of erials such as radium, mesothorium, and cobalt 60 were made for the ernment and private concerns. Over 1,300 radioactive standards were ributed, reflecting the constantly increasing demand throughout the ntry for this service by the Bureau. These included radium gamma-ray dards, alpha-ray standards, radium D+E standards, radioactive iodine, ioactive phosphorus, radioactive carbon, radioactive cobalt, radon stand- s, and rock samples. To protect the health and safety of workers in upations involving the handling or processing of radium, the Bureau ntains careful check over the quantity of radium ingested by such kers and over the quantity of radon present in their working areas.

ctricity

standard apparatus was tested for manufacturers, electric power com- nies, State public utility commissions, university laboratories and private ing laboratories as well as for many agencies of the Federal Government is work involved over 20,000 separate exact determinations. Qualifica- n tests of dry cells and batteries were conducted. Started in 1924, these ts have provided a continuous record of the quality of dry cells and bat- ies manufactured in the United States over a period of 28 years, except a brief interruption during the war. The results of these tests have been nished to all interested Government agencies and have been utilized in nnection with purchases of dry cells and batteries for the Government.



Using the new NBS vibration calibrator (p. 56) to calibrate a vibration pi of the accelerometer type.

Optics and Metrology

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

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

Heat and Power

A total of 2,657 liquid-in-glass thermometers, 85 resistance thermomete and 404 thermocouples and thermocouple materials were calibrated. T number of clinical thermometers tested was 41,499; 20,498 of these rep sented a sampling of over 204,000 thermometers purchased by the Vetera Administration and the U. S. Public Health Service. Tests and calibratic were made of special types of thermometers and thermometric devic Fifty-six viscometers were tested or inspected, and 691 standard viscos

les were supplied to other laboratories for use in the calibration of meters. Calibration tests were made on four hydrocarbon samples in-d for use as reference fuels in knock rating. Seventy-nine fuels and cants, fifty-seven miscellaneous samples, and fifteen oil filter cartridges tested for compliance with Government specifications. Automobile ine economizers, fuel and oil additives, and other automotive devices materials were tested or inspected for the Federal Trade Commission the Post Office Department. Other automotive products tested for rnment agencies included an armored car, a muffler, and seven motor speed governors. Twenty-two nonroutine tests on aircraft electrical ork equipment were conducted for the Bureau of Aeronautics, Depart-t of the Navy.

nic and Radiation Physics

ne cobalt-60 calibration program has expanded markedly in the past ars. During 1952, 300,000 millicuries were calibrated, and applica-were received for calibrations of an additional 2,000,000 Mc that could be accepted. A total of 1,221 radioactive standards were issued this year, uding the I^{131} and P^{32}, Ra D+E, C^{14}, Co^{60}, radon, radium gamma-ray dards, rock samples, and alpha-ray standards. The Bureau measured certified 1,808 radium, mesothorium, and cobalt preparations; tested ores and sludges and 24 water samples for radium content; made 868 n determinations of air samples, 28 miscellaneous gamma-ray determi-ons, and 6 leakage tests. Neutron measurements were carried out for Naval Research Laboratory, the Atomic Energy Commission Instru-ts Branch, the Naval Radiological Defense Laboratory in San Fran-o, the Radium Chemical Company of New York City, and the Univer-of California. Demands for calibrated sources of thermal radiation inued at previous levels with 29 such standards issued.

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

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

emistry

amples received for acceptance and regulatory testing numbered approx-itely 2,600. They covered a wide range of materials: organic protective

coatings and their components; soaps, detergents, and waxes; type
ribbons and carbon papers; metals and alloys; and reagent chemica
service of highly accurate analysis for carbon, hydrogen, and oxyg
organic compounds was maintained and called upon from time to ti
other Government agencies. The Bureau calibrated 585 Magne
devices used to measure the thickness of electroplated coatings.
27,000 NBS standard samples of certified composition were issued.

Mechanics

Physical testing of materials, structures, mechanical apparatus, an
struments for various purposes and calibrations of instruments continu
a high level. In connection with the preparation of specifications for
ing books for the blind, 40 phonographs were tested. Various acoustic
terials were tested for manufacturers and Government agencies. Ca
tions of 388 elastic calibration devices (proving rings, Amsler boxes, ai
weighing cells, etc.) were completed. Tension, compression, bending
sion, and hardness tests were made to determine mechanical perform
and compliance with specifications on a variety of specimens which incl
reinforcing steel, aluminum and copper conductors, wire and fiber rop
pansion joint filler, and hand tools. Tests for compliance with specifica
on an investigative basis were made on 8 mechanical appliances, 14 r
sondes, 4 groups of electrical hygrometers, and 4 groups of mechanical h
meters. Evaluation tests were made on electric razors and watches fo
Federal Trade Commission, on a newly designed postage meter for the
Office Department, and on dewpoint indicators and electrical pressure
ups for the Bureau of Aeronautics, Department of the Navy.

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

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

ganic and Fibrous Materials

The methods of test for automobile and truck tires developed during the t two years in the NBS tire testing program have been incorporated in erim Federal Specification ZZ–T–381f, Tires, Pneumatic, Vehicle and rtable Equipment. Alginate impression materials, denture base resins, ergents for wax elimination, dentrifices, sterilizer oils, vibrators, mechani- amalgamators, sterilizers, and vacuum investors were tested for the ntal Corps of the Air Force, Army, Navy, and the Veterans' Administra- n Dental Service. Three hundred samples of light-sensitive blue paper nufactured in the NBS paper mill, along with standard faded strips, were pplied to textile laboratories for calibrating fading lamps. The demand standard samples of rubber compounding ingredients has continued to large. A total of 6 of the original 7 has been exhausted and replace- nts obtained. A ninth, an oil furnace black, has been established. In operation with the American Society for Testing Materials, steps have en taken toward setting up a "standard" natural rubber. This standard bber with properties determined by the National Bureau of Standards will issued to rubber laboratories desiring to check their apparatus or ocedures.

etallurgy

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

lineral Products

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

Building Technology

Structural tests were made on 71 samples of brick and concrete, masonry units, 87 units of pipe, and 10 prefabricated concrete slabs. tailed evaluation tests were made for the Department of the Army on lo transfer devices for concrete runways, tent frames, and prefabricated w panels. Flamespread tests were made on 25 fabric samples, seven samp of acoustical tile, and eight samples of fire-retardent paint. Exhaust tests were carried out for the Coast Guard on 17 fire extinguishers; n cellaneous fire-resistance tests were made on insecticides, waxes, deckin matches and match cartons, paint cans, roofing, and insulation. Therm conductivity tests on the hot-plate apparatus were carried out on 53 sampl 20 efficiency determinations were made on air cleaners, and ten gasoli lanterns were evaluated. Refrigeration equipment tested included elect drinking water coolers, refrigerated warehouses, refrigerating units, a conditioning units, defrosting mechanisms, and a refrigeration compress A total of 104 bituminous roofing and waterproofing materials were test for various Federal agencies; bituminous road materials tested for t District of Columbia totaled 1,846 items.

Radio Propagation

There was a marked increase in the number of attenuators calibrated the X-band region, with most of the measurements made around 9300 M The large increase was due both directly and indirectly to requests f calibration by defense agencies. For the first time a complete system w set up for calibrating attenuators in the 1 x 2-inch waveguide size (395(5850 Mc). Forty-six VHF and microwave frequency meters covering range from 300 to 26,000 Mc were calibrated. Forty-two waveguide ar coaxial-type attenuators were calibrated. A number of power meters we calibrated, including several in the UHF region. Calibrations and tes were made on 97 types of high-frequency radio equipment for the Gover ment and the public. Standard frequency and time signals were broadca continuously from WWV (Beltsville, Md.) and WWVH (Maui, T. H.), f use in the calibration and test of frequency and time standards by the arme services, research laboratories, and various industries.

Weights and Measures

The Bureau tested and calibrated master railway track scales, railway te cars, commercially operated railway track scales, and other large capacit scales. Special tests were concluded on cordage-measuring devices, smal capacity scales, and ice-cream measure-containers. Definite methods of te were devised and refined. Calibration of large standards of mass was con tinued. These calibrations included 50-pound weights of cast iron and al weights over 50 pounds that were submitted to the Bureau by Governmen agencies and industry.

18. Cooperative and Advisory Activities

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

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

Federal Specifications

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

Mechanical and Electrical Equipment

The Bureau was consulted on a variety of technical problems related to motor vehicles. The numerous problems handled were relative to Govern-

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

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

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

Rubber

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

Fungus Proofing of Leather

The Second World War emphasized the need for a dressing for shoes whi would maintain them in a serviceable condition and prevent their atta by mildew in the tropics. A satisfactory treatment was developed for t Quartermaster General, which contained paranitrophenol as the acti fungicide. Experience has shown that at least 0.2 percent (more than 0

ercent is toxic) of paranitrophenol must be added to the leather to prent mildew growth.

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

Mineral Products

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

Building Technology

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

agencies on various phases of heating, refrigeration and air conditioning a
on roofing, flooring and related problems; technical advice was given to t
Army and the Navy on contracts for the repair and replacement of roofi
and floor coverings.

Mathematics

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

Radio Propagation

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

National Cooperation

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

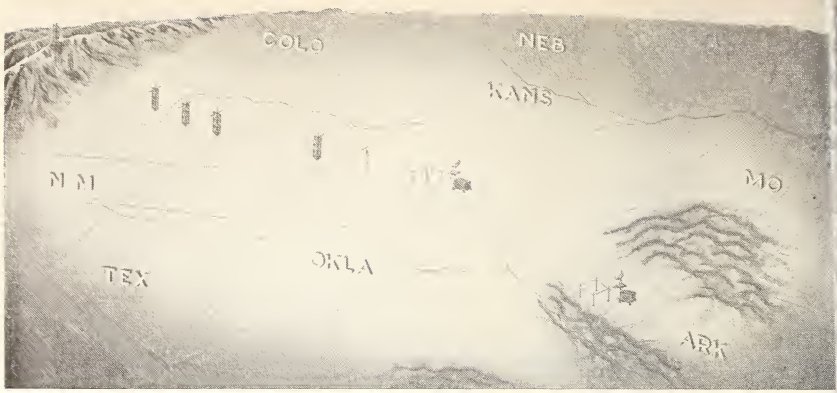
Weights and Measures

As custodian of the national standards of measurements the Bureau provides calibration services to the Federal Government, state and municipal governments, universities, industry, and private laboratories. The transition of the basic standards of length and mass, and of the derived standards of capacity, to the channels of industry and trade is a matter of great economic importance to the producing, manufacturing, processing, and distributing agencies in this country and to all purchasers of commodities. To aid in this work, the Bureau has an Office of Weights and Measures which assists in improving the standards of efficiency and coverage and increasing the degree of uniformity of State weights and measures supervision throughout the United States. A program of assistance to state and local departments of weights and measures as well as to business and industry has been pursued.

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

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

Actions of the 37th National Conference included the adoption of further specifications and tolerances for commercial weighing and measuring devices. Recommendations were made on soap bars and cakes; ice cream and ices on sticks; peat moss in package form; Permalite, or any material or substance of the nature or character thereof; tomatoes in package form; prepackaged meats at retail; fractional terms of ounces; quantity declara-



Location of transmitter and receiver sites used in radio propagation studi (p. 62). Two transmitters are on Cheyenne Mountain, Colorado, at elevatio of 9,000 and 7,000 feet. Permanent receiver installations are located near Ke drick, Karval, and Haswell in Colorado, and Garden City and Medicine Lodge Kansas. Mobile units operate near Anthony, Kansas, and Fayetteville, Arkansa

tions on commodities in package form; and meats, fish, cheese, and poultr in plastic wrappings and casings.

Scientific and Technical Groups

By actively participating in the projects of professional societies and stand ardizing bodies, the Bureau plays an important part in the development o test methods and criteria, in the application of scientific discoveries, and i fundamental research programs of a national nature. In this way the Bu reau assists in developing and improving engineering standards, purchas specifications, and building and safety codes. NBS staff members participat in over 100 national groups such as the Acoustical Society of America American Society for Testing Materials, American Standards Association American Society of Textile Chemists and Colorists, American Concret Institute, American Geophysical Union, American Institute of Electrica Engineers, American Society of Heating and Ventilating Engineers, Amer ican Society of Mechanical Engineers, Institute of Radio Engineers, Instru ment Society of America, National Fire Protection Association, Optica Society of America, Society of Automotive Engineers, Society of Plastic In dustry, American Petroleum Institute, American Ordnance Association, American Chemical Society, and National Association of Corrosion Engineers.

The Bureau's participation in the work of these and related organizations is largely through the activities of technical committees. Sixty members of the staff maintain personal membership in the American Society for Testing Materials. Thirteen of these hold the chairmanships of main committees dealing with such diverse subjects as magnetic properties, magnesium oxy chloride cements, gypsum, asbestos products, porcelain enamel, electrical insulation, emission and absorption spectroscopy, textiles, wax polishes, plas-

adhesives, and analysis of metals. Forty-three other staff members are rmen of working committees while a still larger number lend assistance erving on technical committees and task groups so that in all about 425 mitteeships are held by Bureau personnel.

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

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

lor Science

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

esearch Associate Program

The research associate plan is an arrangement whereby technical, in strial, and commercial organizations can support work at the Bureau on rojects which are of special interest to them, yet of sufficient general in rest to justify use of Government facilities. Research associate projects

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

Since the research associate plan was established in 1920, more than organizations and individuals have supported cooperative research at Bureau. Many of the projects have been extremely specific and there of relatively short duration. Others, such as that supported by the Am can Dental Association, have been directed toward fundamental resea in the field; this project has been active since 1930. Fourteen groups now supporting 35 research associates at NBS. Cooperative projects underway in pyrometry, solid adsorbents, sugar refining, electrodeposit plumbing systems, gas orifice meters, dental materials, cement test crystallography, portland cement, porcelain enamel testing, asphalt ro ing products, and reinforced concrete. During the year fifteen papers the various fields were published as a direct result of the research associ program work.

International Cooperation

The National Bureau of Standards is active in such groups as the Int national Union of Chemistry, International Telecommunications Uni International Committee on Weights and Measures, International Scient Radio Union, International Commission on Illumination, and Internatio Commission for Uniform Methods of Sugar Analysis. These societies d largely with the establishment and maintenance of international scient standards and the establishment of values for scientific constants. Anotl phase of international cooperation involves a program whereby scient or diplomatic representatives from other countries are accepted at N as guest workers or visitors. Both aspects, which are important to the Unit States in terms of commerce and trade as well as the international polic of the Government, are coordinated on the diplomatic level by the Sta Department.

International Intercomparison of Standards

The second international intercomparison of photometric standar which has been in progress for the past several years, was complete a final report was received from the International Bureau of Weights ai Measures (BIPM) in Paris. Adjustment of the units of the various cou tries is not contemplated at this time. However, if adjusted on the basis the NBS values the maximum change in any U. S. value would be 0.3 pe cent; other countries would have maximum adjustments ranging from 0.4 to 0.86 percent.

group of NBS saturated cadmium standard cells was taken to Paris comparison with those maintained at the International Bureau of ights and Measures and those sent in by other national laboratories. A y of the results of the 1950 intercomparison showed that the electrical ts of the various cooperating nations have been maintained satisfactorily e the 1939 intercomparison. The study also showed that the change to new absolute units as carried out in 1948 has been accomplished satistorily.

ew Threads

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

ternational Meetings

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

ternational Relations

Under authority of the Department of Commerce and several educational xchange programs of the Department of State, such as the Mutual Secuty Act of 1951, Foreign Economic Assistance Act (Point IV), the United tates International Educational Exchange Act (Smith-Mundt Act), the ulbright Act, and others, the Bureau conducts visitor and trainee programs hich permit foreign scientists and technicians to work, study, and visit at he Bureau. These activities not only strengthen the relations of this country ith other nations, but also permit the National Bureau of Standards to keep ore closely in touch with scientific developments in other countries and enefit from them.

The Bureau also renders services to foreign countries in the form of te calibrations, and exchange of standards, and also exchanges publications a world-wide basis. An example of an advisory service rendered to a fore country by the Bureau is shown by the service given to Costa Rica under t Point IV program. A staff member has been conducting a survey to det mine the "standards" requirements of Costa Rica and to make recommen tions for the establishment of a standards research agency. This service w be supplemented by a program for training personnel in the United Sta for work in such an institution. Plans are also being drawn for assistar to Brazil in establishing a modern paints, varnishes, and lacquers laborato

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

Publications

The results of the Bureau's work are to a considerable extent present in the form of papers and reports. During the last year these total some 1,500, exclusive of those reports which have to do with calibrati services and testing. Over 1,000 reports, classified and unclassified, we prepared; most of these were issued to other Government agencies, pa ticularly the Department of Defense, on projects supported by transferr funds.

Approximately 500 papers and documents were issued for formal public tion. Of these, some 300 consisted of scientific and technical papers; 11 papers were published in the National Bureau of Standards *Journal of R search*; the remainder were published in the familiar scientific and tecl nical journals of various professional, engineering, and trade organization In addition, 118 summary reports were published in the Bureau's *Technic News Bulletin*. The third monthly periodical of the Bureau, *Basic Radi Propagation Predictions*, presented each month, for a one-month perio three months in advance, radio-propagation data needed in determinin the best frequencies to use in long-range radio communications.

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

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

SCIENTIFIC AND TECHNICAL DIVISIONS AND SECTIONS

ELECTRICITY

esistance Measurements. Inductance and Capacitance. Electrical Instruments. Magnetic Measurements. Applied Electricity. Electrochemistry.

OPTICS AND METROLOGY

hotometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Gage.

HEAT AND POWER

emperature Measurements. Thermodynamics. Cryogenics. Engines and Lubrication. Engine Fuels. Cryogenic Engineering.

ATOMIC AND RADIATION PHYSICS

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

CHEMISTRY

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

MECHANICS

Sound. Mechanical Instruments. Aerodynamics. Engineering Mechanics. Hydraulics. Mass. Capacity, Density, and Fluid Meters.

ORGANIC AND FIBROUS MATERIALS

Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

METALLURGY

Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurg Corrosion.

MINERAL PRODUCTS

Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concre ing Materials. Constitution and Microstructure. Chemistry Mineral Products.

BUILDING TECHNOLOGY

Structural Engineering. Fire Protection. Heating and Air Conditionin Floor, Roof, and Wall Coverings. Codes and Specifications.

APPLIED MATHEMATICS

Numerical Analysis. Computation. Statistical Engineering. Machin Development.

ELECTRONICS

Engineering Electronics. Electron Tubes. Electronic Computers. Elec tronic Instrumentation.

RADIO PROPAGATION

Upper Atmosphere Research. Ionospheric Research. Regular Propaga tion Services. Frequency Utilization Research. Tropospheric Propa gation Research. High Frequency Standards. Microwave Standards.

ORDNANCE DEVELOPMENT
ELECTROMECHANICAL ORDNANCE
ORDNANCE ELECTRONICS

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

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

OFFICE OF BASIC INSTRUMENTATION

OFFICE OF WEIGHTS AND MEASURES