ANNUAL REPORT

OF THE

DIRECTOR
BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1918

WASHINGTON
GOVERNMENT PRINTING OFFICE
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Washington, D. C.

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and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

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REPORT

OF THE

DIRECTOR, BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 1, 1918.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1918.

1. FUNCTIONS, ORGANIZATIONS, AND LOCATION.

Before describing in detail the various scientific and technical problems in which the Bureau of Standards is engaged, the following brief statement as to its functions and organization may be helpful to those unfamiliar with the subject of standardization in the broad and modern sense.

The standards with which the Bureau is authorized to deal may be conveniently classed as follows: Standards of measurement, standard values of constants, standards of quality, standards of mechanical performance, and standards of practice.

1. STANDARDS OF MEASUREMENT.

A standard of length may be taken as an example of a standard of measurement. It must be a length which is unchanging, reproducible, and capable of being compared with the working standards used in the most precise scientific work or with those used in commerce and industry. The fundamental standard must be subdivided and working standards prepared of these parts, and for the measurement of greater lengths standards must be prepared which are multiples of the fundamental standard. This process of subdividing and multiplying the standard involves difficulties as great as those met with in the preparation of the fundamental standard itself.

The construction of a set of standard weights from a single unit is also an illustration; a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. When the standard of length or weight has been found with as many desirable qualities as possible, and before the working standards of the subdivisions or multiples can be prepared, the question as to the method of comparison arises, which again involves the solution of difficult scientific problems in connection with the balance or the methods used. These balances range from that capable of measuring the thousandth part of a milligram to the large testing machine capable of measuring a load of thousands of tons. The complete range must be covered, which involves

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STANDARDS	PURPOSE
1 **STANDARDS OF MEASUREMENT** Reference and working standards for measurements of all kinds, including fundamental and derived STANDARDS OF MEASUREMENT for expressing the quantitative aspects of space, time, matter, energy, motion, and of their interrelations. By definition, specification, or material standard, covering, for example, length, area, and volume; mass, weight, density, and pressure; heat, light, electricity, and radioactivity, including quantity, flux, intensity, density, etc.	To aid ACCURACY IN INDUSTRY through uniform and correct measures; To ASSIST COMMERCE IN SIZE STANDARDIZATION of containers and products; To PROMOTE JUSTICE IN DAILY TRADE through systematic inspection and regulation; To facilitate PRECISION IN SCIENCE and TECHNOLOGIC RESEARCH through calibration of units, measures, and instruments involved.
2 **STANDARD CONSTANTS** Natural standards or the measured numerical data as to materials and energy, known as physical or STANDARD CONSTANTS, i. e., the fixed points or quantities which underlie scientific research and industrial processes when scientifically organized. Mechanical equivalent of heat, light, and electricity and of gravitation; specific densities; viscosities; melting and boiling points; heat capacity; heats of combustion; velocity of propagation of light; conductivities of materials to heat and light; electrochemical and atomic weights and many similar magnitudes determined experimentally with maximum precision and referred to fundamental standards of measure.	To SERVE as an EXACT BASIS for scientific study, experiment, computation, and design; To FURNISH an EFFICIENT CONTROL for industrial processes in securing reproducible and uniformly high quality in output; To SECURE UNIFORMITY OF PRACTICE in graduating measuring instruments, compiling tables, in standards of quality and performance, and wherever uniformity is desirable; To AID LABORATORY RESEARCH BY REDUCING ERRORS and uncertainty caused by use of data of doubtful accuracy.
3 **STANDARDS OF QUALITY** Specifications for material (by description, sample, or both), known as STANDARDS OF QUALITY, fixing in measurable terms a property or group of properties which determine the quality. The numerical magnitude of each constituent property pertinent to the quality involved, and specific magnitude in units of measure of such significant factors as uniformity, composition, form, structure, and others.	To secure HIGH UTILITY in the PRODUCTS of industry by setting an attainable standard of quality; To furnish a SCIENTIFIC BASIS for FAIR DEALING to avoid disputes or settle differences; To PROMOTE TRUTHFUL BRANDING and ADVERTISING by suitable standards and methods of test; To PROMOTE PRECISION and AVOID WASTE in science and industry by affording quality standards by which materials may be made, sold, and tested.
4 **STANDARDS OF PERFORMANCE** Specification of operative efficiency or action, for machines and devices, STANDARDS OF PERFORMANCE, specifying the factors involved in terms susceptible of measurement. Numerical statement of speed, uniformity, output, economy, durability, and other factors which together define the net efficiency of an appliance or machine.	To CLARIFY THE UNDERSTANDING between maker, seller, buyer, and user, as to operative efficiency of appliances and machines; To make EXACT KNOWLEDGE THE BASIS OF the buyer's choice; To STIMULATE AND MEASURE MECHANICAL PROGRESS.
5 **STANDARDS OF PRACTICE** Codes and regulations impartially analyzed and formulated after study and experiment into STANDARDS OF PRACTICE for technical regulation of construction, installation, operation, and based upon standards of measurement, quality, and performance. Collation of standard data, numerical magnitudes, and ranges of the pertinent factors defining quality, safety, economy, convenience, and efficiency.	To FURNISH for each utility a single IMPERSONAL STANDARD of practice as a BASIS FOR AGREEMENT of all interests clearly defined in measurable terms; To INSURE EFFECTIVE DESIGN and INSTALLATION of utilities of all kinds; To PROMOTE SAFETY, EFFICIENCY, and CONVENIENCE in the maintenance and OPERATION of such utilities; To SECURE UNIFORMITY OF PRACTICE where such is practicable, and EFFECTIVE ALTERNATES in other cases.

not only a large number of working standards, all of which must agree with the fundamental standard, but apparatus suitable for the comparison of these standards with all of the lengths or weights found in practice.

These steps and equipment are absolutely essential in order to secure uniform measurements of length or weight throughout the country, and they have their counterpart in every quantity that has to be measured, whether it be length, weight, temperature, heat, light, or the various electrical measurements or other standards of measurement. These standards in one form or another are involved in practically every scientific investigation, industrial process, engineering structure, or commercial transaction.

2. PHYSICAL CONSTANTS.

There are many fixed relations between physical quantities, the values of which it is extremely important to know. These values are usually termed "physical constants," and are used in every branch of scientific work or industry. The amount of heat required to change a pound of water into steam under normal conditions and the relation between heat and mechanical energy are two important physical constants; their values are used in practically every computation in connection with the designing of steam engines and boilers, the tests of their efficiencies, or the measurement of their output. The amount of heat required to turn liquid ammonia into vapor or the amount of heat required to melt a pound of ice are constants equally important in the refrigerating industries. The value of the relation between electrical and mechanical energy is involved in many important commercial transactions concerned in electricity.

Accurate and authoritative values of these constants are just as essential as in the case of standards of measurement. Many of these now in use are old and obsolete and need redetermination by means of the best modern facilities for physical measurement. Their determination involves the most difficult and precise work in all branches of physics and chemistry—a fact not generally known by those not engaged in the scientific or technical work where these constants are used.

3. STANDARDS OF QUALITY.

A standard of quality for a given material may sometimes take the form of a sample of that material with which other materials of the same kind can be compared, but this is generally a makeshift of the poorest sort. It is only resorted to in the absence of definite and reliable specifications in terms of measurable properties; that is to say, a standard of quality of a material usually takes the form of a specification or definition of its properties, involving, of course, the measurement of those properties by means of the usual standards of measurement. A certain kind of steel, a cement, a paint, an oil, or a paper or cloth is found by use to be good or poor. The questions then arise, Why is it good or poor; What are the physical or chemical properties or the particular combination of elements which make it of good or poor quality; How are its properties to be measured or its constituents determined? These are questions for the laboratory to answer and involve physical and chemical investigations of the most difficult sort.

A standard of quality for a given material necessarily takes into account the purpose for which the material is to be used; to set the standard too low results in losses, poor efficiency, and even loss of life; to make it too high may result precisely in the same thing; that is to say, the material must be suitable for the purpose intended, and the Bureau's investigations in connection with the properties of materials are to enable the user of these materials, first, to select intelligently the material best suited for the purpose; second, to specify it in terms which the producer can not mistake; and, third, to make the necessary tests to ascertain whether or not the material supplied is in accordance with the specifications.

The actual testing of materials by the Bureau of Standards to ascertain whether or not they comply with specifications is confined almost exclusively to Government purchases, but in making these tests (in which the Bureau has had the hearty cooperation of practically all the departments of the Government service) it is compelled to make many investigations concerning the properties of materials, their specification and measurement. While this work is of great value in placing Government purchases on a correct business basis, the results of the investigations as to the properties of materials and the information gained in testing Government supplies are even more important to the general public and are distributed in the form of suitable publications.

The Bureau does not compete with private testing laboratories, but endeavors to assist them by the development of standard specifications, methods of measurement, and other matters where uniformity is desirable, much of which information, as stated above, is secured in connection with the testing of materials purchased by the Government and a close observation of their use.

The time is not far distant when it will be required that all materials bought or sold shall be as represented, but it should be kept in mind that this is impossible except in the case of those materials where proper standards of quality and methods of measurement have been developed. It must not be assumed that the purchaser or user is the party principally benefited in the development of such standards; on the contrary, the manufacturer, first of all, is interested in the quality of all things which affect the quality of his product, and while the Bureau's efforts in this field are devoted principally to the pointing out and measurement of those properties upon which the quality of the materials depends, it is to be regretted that its force and equipment are insufficient to render more assistance to manufacturers with a view to a direct improvement of those parts of the process upon which the quality of the output depends.

4. STANDARDS OF PERFORMANCE.

The value of an instrument, device, or machine almost always depends upon the efficiency of its performance. In such cases it is necessary to state the performance desired or guaranteed in terms which are correct and susceptible of measurement. As in the case of standards of quality, the standard involved is more often in the form of a specification, but specifications are useless unless based upon correct scientific and mechanical principles and supplemented with a statement of the method to be used in ascertaining whether or not the specifications or guaranties have been complied with.

The performance of an engine or boiler, a pump, an electrical generator or motor, a weighing device, or a telescope can usually be measured, but the quantities to be measured and the method used must be specified correctly and understood by all the parties concerned in the construction, purchase, or use of such apparatus. To do this properly involves the use of standards of measurement, standards values of constants, and standards of quality. The Bureau of Standards does not attempt to cover this field completely, but only those cases where there is a lack of definite information upon which to base specifications and only to the more important classes of apparatus. To secure this information involves investigations quite as scientific in character and as difficult as in the case of other standards, as well as a knowledge of technical and manufacturing processes.

The Bureau's activities in this field have only been developed to a slight extent and almost entirely in connection with Government purchases. It has had in this, as well as in the field of the properties of materials, the most hearty cooperation of the various Government experts, manufacturers, engineers, and technical societies.

5. STANDARDS OF PRACTICE.

Standards of practice are generally involved in the enactment of laws when technical and scientific matters are concerned, in the ordinances relating to the regulation of public utilities, and in the establishment of building and safety codes. Like standards of performance, they are dependent upon standards of measurement and standards of quality and are of the most vital importance in questions pertaining to the welfare and safety of the public. In a field so broad the Bureau can touch only upon the more important aspects of the work, where national uniformity is desired—fields which can not be covered efficiently in private laboratories.

6. RELATION OF THE BUREAU'S WORK TO THE PUBLIC.

It is perfectly obvious, even to one unfamiliar with the subject, that the maintenance on the part of the Government of correct standards of measurement or quality or performance calls for continuous scientific and technical investigations of the highest grade, involving the most competent expert services and the best scientific equipment. When this is accomplished, there still remains the serious problem of making the results available and useful to the public.

The Bureau compares with its own standards of measurement the standards or measuring instruments of States, cities, scientific laboratories, educational institutions, manufacturers, Government bureaus, or the public, for which a nominal fee is charged, except in the case of the National and State Government institutions. It gives advice concerning these standards or their use, whether it be in connection with the enactment of laws, regulations, or ordinances concerning the weights and measures of everyday trade or in connection with precision standards used in scientific work and the industries. It gives advice upon request to State and city officials, public-service commissions, and public-utility corporations regarding the standards of measurement, or quality, or performance involved in legislation or regulation pertaining to the public utilities. Many questions of

disagreement between the public and utility companies as to these matters are referred to the Bureau for advice or adjustment, often avoiding unfair or inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. As far as possible such information is given in the form of publications upon definite subjects.

It must not be inferred from the above that the Bureau's activities are devoted principally to the interests of the user or consumer. The fundamental facts regarding standards of measurement, quality, or performance are the very things which most deeply concern manufacturers; they are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output. It may be said that the Bureau occupies somewhat the same position with respect to the manufacturing interests of this country that the bureaus of the Department of Agriculture do to the agricultural interests. Many industries are just beginning to realize the importance of precise methods of measurement and scientific investigation, which, in practically every case, involve some kind of measurement.

It is upon quality as well as upon price that competition must finally depend, whether in domestic or foreign commerce. The use of exact methods and scientific results is the greatest factor in the improvement of quality, efficiency, or the development of new industries. The educational value of the Bureau's work in this respect is almost entirely unknown to the general public, and yet the Bureau receives hundreds of letters, as well as many personal visits from manufacturers, seeking information as to standards of measurement, how to use them, how to measure the properties of materials, or as to the fundamental physical and chemical principles involved; also, what is of even greater importance, how to initiate and carry out scientific investigations and tests on their own account in their particular fields of work.

The importance of maintaining scientific institutions having to do with standardization and the application of precise measurements to the industries has been recognized by all the leading countries of the world. Great Britain maintains the Standards Department of the Board of Trade, which is in charge of the standards and inspection service of the trade weights and measures; also the National Physical Laboratory, whose functions include matters pertaining to scientific and technical standards, physical constants, and to some extent the properties of materials. The Laboratoire d'Essais, of France, while not as extensive as the English institution, is charged with similar duties. Germany maintains three such institutions—the Normal-Eichungs Kommission, equipped with the buildings, personnel, and apparatus necessary in standardizing and controlling the weights and measures of trade; the Physikalisch-Technische Reichsanstalt, covering testing and investigations in connection with scientific and technical standards other than weights and measures; and the Prussian Government maintains the Materialprüfungsamt, a large institution devoted to the investigating and testing of structural, engineering, and other materials.

It is generally recognized that these institutions have been exceedingly important factors in the industrial progress of these countries.

7. RELATION OF THE BUREAU'S WORK TO THE GOVERNMENT SERVICE.

The bureaus of the Government engaged in scientific and technical work are necessarily dependent upon standards of measurement of every variety. In addition, many of them are engaged in the design, construction, and specification of a great variety of special apparatus, in which the principles of mechanics, heat, optics, electricity, and chemistry are involved and are vital to their efficiency and successful operation. In such matters the Bureau has been consulted most freely by the War and Navy Departments, and various other military departments of the Government, including the Railroad Administration, Shipping Board, Fuel Administration, Food Administration, and National Advisory Committee for Aeronautics; also the Post Office Department, the Department of Agriculture, the Public Health Service, and others.

The engineering and building construction in progress at all times by the Government is exceedingly great, both in variety and magnitude; in all of it a knowledge of the materials employed is of fundamental importance from the standpoints of economy, efficiency, and safety. The work of testing and investigating the properties of structural materials was taken up and is carried on primarily for the purpose of securing the information needed by the Government service in its structural work. This information is as necessary to the public in construction work, and every effort is made by the bureau to make its findings in a form available to the public generally. The demands for information of this sort have come from practically all Government bureaus and establishments, but especially so in connection with the structural work carried on by the Office of the Supervising Architect, the engineering branches of the Army, the Bureau of Construction and Repair of the Navy, the Panama Canal, and the Reclamation Service.

The Bureau of Standards serves as a testing bureau for the various departments of the Government when called upon, and as such is assisting to place Government purchases upon an economical and businesslike basis. The example of the Government in such matters has a far greater influence upon the public than is generally supposed. The Government can do no greater service to the country than to place its own purchases upon a basis which may be taken as a standard by the public at large. This work involves the specification of a wide range of structural and miscellaneous materials and their testing, when delivered, to ascertain whether or not they comply with the specifications. This is especially important, since such materials are purchased by means of competitive bids, a method resulting in much fraud and injustice unless suitable standards are established and successful bidders held absolutely to this standard in making deliveries. Furthermore, most purchasing officers are realizing the great importance of having such testing done by a disinterested institution equipped with the scientific and other facilities for performing the service in a manner that is fair to both parties concerned in the purchases.

Among the many Government bureaus and establishments which have utilized the Bureau of Standards as a testing institution in connection with the purchase of supplies may be mentioned the Government Printing Office, in connection with the purchase of paper, inks, and printing supplies; and the Post Office Department, in connection with the purchase of paper, twine, textiles, etc. A wide range of materials has been tested for the Quartermaster's Department of the Army, the Paymaster's Department of the Navy, and the Panama Canal. The General Supply Committee has called upon the Bureau for assistance in the specification of all sorts of supplies and equipment, as well as the testing of samples submitted by bidders of the supplies bid upon. Practically every branch of the Government service, including the District of Columbia, utilizes the Bureau of Standards as a testing bureau. Here again, as in other fields of the Bureau's activities, it gains much useful knowledge which is given to the public in the form of suitable publications.

Many bureaus of the Government service are charged with the administration of laws and the establishment of regulations in which scientific data are vital. This is true to a much greater extent than is generally supposed. The Bureau of Standards has cooperated freely with such branches of the Government and the service rendered has involved every department of physics and chemistry covered by the Bureau's activities. The neglect of such matters in the past has been a frequent source of misunderstanding and litigation between the Government service and the public. Conspicuous examples of bureaus to which such assistance has been given are the Customs and Internal Revenue Services; the Steamboat-Inspection and Coast Guard Services, in the promulgation of safety regulations; and the Bureau of Navigation of the Department of Commerce, in the administration of laws regulating the use and inspection of radiotelegraphy.

8. ORGANIZATION.

The organization of the Bureau's scientific and technical staff is based upon the nature of the expert service involved rather than upon the classes of standards. For example, the division of weights and measures has to do with all matters pertaining to standards of length, mass (weight, as it is commonly termed), time, density, and similar questions, whether they arise in connection with the precision standards used in scientific investigation, the master standards of manufacturers, or the ordinary weights and measures of trade. A standard of quality or performance where any of the above measurements form the fundamental and most important factor would be referred to this division.

The division of heat and thermometry has to do with heat standards, the testing of heat-measuring apparatus, the determination of heat constants, of which there are many, and all investigations pertaining to quality or performance where heat measurement is the essential and predominating factor.

Similarly, the electrical division is concerned with all the electrical problems that may be taken up at the Bureau, whether in connection with the various electrical standards of measurement, electrical constants, the electrical properties of materials, or the performance of electrical equipment.

Questions in optics enter into standards of all kinds to a greater extent than has been supposed; hence, there is an optical division provided, with experts in spectroscopy, polarimetry (used in sugar analysis), color measurement, the principles of optical instruments, and the measurement of the optical properties of materials.

Practically all investigations concerning the various classes of standards involve chemistry in one form or another. There are also many chemical standards and questions which arise in connection with chemical work generally, especially in the industries; hence, there is a chemical division, cooperating with every other division of the Bureau, as well as taking care of the questions of a purely chemical nature that come to the Bureau and which fall within its functions.

In the case of the more important technical fields, divisions have been formed dealing more specifically with large and important classes of materials, but many of the purely scientific questions involved would be handled by one of the above-mentioned scientific divisions or jointly with it. The work of the technical divisions is just as scientific in character, but deals more specifically with manufactured products.

The work of the structural engineering and miscellaneous materials division includes the investigation, testing, and preparation of specifications for these materials, such as the metals and their alloys, stone, cement, concrete, lime, the clay products, paints, oils, paper, textiles, rubber, and other miscellaneous materials.

The division of engineering research makes investigations and tests regarding the performance and efficiency of such instruments, devices, or machinery as the Bureau may take up that do not fall directly under one of the scientific divisions. The division is a small one and its work is devoted almost exclusively to assistance given other departments of the Government and the General Supply Committee in designing, specifying, or testing equipment. It should in time form one of the more important branches of the Bureau's work.

The questions pertaining to the manufacture, specifications, testing, and use of the metals and their alloys have become so important that a division known as the metallurgical division has been formed of the experts engaged in these problems.

The employees engaged in clerical work, purchasing, files, records, accounting, and library are known as the office division, while those employed in the operation of the mechanical plant, the various shops, and the care of the buildings and grounds form the engineering and construction division.

9. LOCATION.

The laboratories of the Bureau of Standards are located in the northwest section of Washington, on Pierce Mill Road, near Connecticut Avenue, and are reached by the Chevy Chase car line. They were located outside of the business center of Washington in order to insure freedom from mechanical, electrical, and other disturbances common to the business and more thickly populated sections of the city. Furthermore, the area of ground necessary precluded a site near the city. It has been found by experience that the efficiency of the employees, especially those engaged in testing and scientific investigation, has been greatly increased by the location of the laboratories in a section free from the ordinary disturbances of city life.

II. SCIENTIFIC AND TECHNICAL DIVISIONS.

1. WEIGHTS AND MEASURES.

[Length, area, volume, mass, density, pressure, and time, including researches on units and standards, measuring methods and instruments, specifications and tolerances, and the standardization incident thereto for inspectors of weights and measures, manufacturers of measuring appliances, scientific and technical laboratories, Government bureaus, engineers, and the general public.]

LENGTH.

(The design, improvement, and investigation of length-measuring apparatus, calibration and test of yard bars, meter bars, geodetic tapes, level rods, haemacytometer apparatus, cement sieves, expansivity of solids.)

Military Work in Connection with Weights and Measures.

Other work having a military bearing, yet proper to be mentioned here, includes the following:

In connection with the test of coke ovens the Division of Weights and Measures tested and adjusted the railroad track scales used for weighing the coal, etc., used in the test. Parts of a new ordnance design were weighed and the position of the center of gravity determined for the Ordnance Department. Considerable consulting work has been done in relation to tolerances on screw threads, investigation of systems for screw-thread tolerances, and improvements in design of measuring machines.

Cooperation has been afforded in the design of precision micrometers of two types, one for measuring outside dimensions and one for measuring inside dimensions, manufactured for the bureau by the Mount Wilson Solar Observatory. An arrangement of projection lantern has been devised for the determination of the angles of screw threads, which is a great improvement over the apparatus previously employed in this work.

A contact indicating device has been designed and constructed which is found to be very sensitive and gives promise of many useful applications; a torque measuring instrument for use in connection with precision micrometers has been constructed, and the specifications and general features of design for an end standard measuring machine were worked out in conference. A new method for determining the paths of artillery projectiles in flight has been proposed and turned over to the military authorities. This division is also cooperating in the development of a device for synchronizing machine guns to shoot between the aeroplane propeller blades and an investigation of a machine for gauging rifle barrels is now being conducted.

This division has also conducted a research to determine the elastic indentation which takes place when spherical surfaces are employed, as they are in much of the gauge-standardization work, and the correction resulting from the indentation has been determined.

Many computations have been made covering such subjects as the springs used in machine gun adjustments, tables for use in measuring

screw threads, table for constants for the three-wire method of screw measurement, and a table of metric equivalents, which now has been published as a supplement to Circular No. 47.

A few communications have been issued in connection with military work, among which may be mentioned one which calls attention to some fundamental misconceptions regarding use of screw-thread gauges, two on the precision test of micrometers, and one on symbols for screw-thread notation. This last has been adopted by the Committee on Screw-Thread Tolerances of the American Society of Mechanical Engineers.

Additional Consulting Work.

In addition to the consulting work on track scales and testing equipment and on specific military problems, the Bureau has done work of similar character in reference to the use of spring scales for investigating quarry stone under the Office of Public Roads; depot and wagon scales for the Engineer Corps of the Army; platform scales and parcel-post scales for the Post Office Department; specifications for freight-house scales for the Southern Railway; specifications for hopper scales for the Pennsylvania Railroad and for the American Railway Association; specifications for hopper scales for manufacturers; an invention for obtaining an automatic compensation for automatic grain scales for the inventor and manufacturer; prescription scales for the Medical Supply Depot of the Army; investigation of a new design of flexure plate scale for parcel-post work; design of 5,000-pound weights for the New York Central Railroad; autotruck scales, wagon scales, paper weighing scales, platform scales, and specifications for 500-pound standard weights, these requests coming from various sources.

A series of charts for computing scales were examined and report rendered to a manufacturer of computing scales. A careful study of a mechanical device for measuring cloth was made for the manufacturer, special attention being paid to its acceptability for use in trade.

Length Measures.

During the fiscal year 2,071 tests for accuracy of linear measurements were made upon the following articles:

Line standards and measuring scales (tested or ruled)	27
Tapes	695
Level rods	29
Sieves	51
Samples of sieve cloth	14
Polariscope tubes	46
Hæmacytometer chambers	228
Micrometer calipers, vernier calipers, end standards, disk gauges, etc., for the equipment of the gauge section	919
Miscellaneous articles	62

Observations were completed on six State standards of length, a complete calibration of a bar for the electrical division of the Bureau was made, and 24 intervals on a Pratt & Whitney bar were determined.

Among the miscellaneous articles to which length tests were applied were slotted drums for an oscillograph timer, a master chart for compass dials, Johansson gauge blocks, steel balls, and viscosimeters. Besides the routine testing and the investigations noted,

mention should be made of a considerable number of informal tests and investigations for the gauge section, for other divisions of the bureau, and for the Army.

A thorough investigation and test was made of an end comparator at the Washington Navy Yard with a view to ascertaining whether the apparatus was suitable and sufficiently accurate for the work being done upon it. The results showed that a more accurate comparator was needed, and one is being purchased for this work to conform to recommendations made by the bureau. A careful calibration was also made of a Gaertner comparator for the gauge section of the bureau.

Special investigations were made also of the accuracy of the large dividing engine and of the special end comparator in use in the Bureau.

Hæmacytometers.

During the previous fiscal year the test of hæmacytometer chambers and pipettes was taken up and specifications were prepared for the test of this apparatus. These are important instruments widely used by physicians and bacteriologists in counting the number of corpuscles in a given quantity of blood. Close cooperation has been had with the manufacturers, and during the past year two prominent manufacturers of hæmacytometers visited the bureau for consultation. As a result of the bureau's work, there has been a gratifying improvement in the instruments submitted for test. These instruments are extensively used by the medical departments of the Army and Navy, and in one lot of instruments submitted for Government use excessive errors were found in the chambers. A special device is being designed to facilitate the test of these instruments.

Expansion of Insulating Materials.

Numerous synthetic insulating materials such as "bakelite," "condensite," "formica," etc., have been tested and heat treated to obtain necessary information in connection with the Bureau's spark plug investigations. It has been shown that, without exception, the colloidal substances mentioned above are not suitable for use in delicate apparatus which may be subjected to temperatures above 60° C. The thermal expansion soon vanishes and continued treatment shows marked contraction and loss of weight of the specimen. A paper on this subject will soon be prepared. Specimens of tile and porcelain were also investigated for their thermal expansion properties.

New Equipment for Measuring Expansion.

A new furnace having a limiting temperature of 1,000° C. has been installed, and tests were made above 900° C. in connection with investigations on steel for machine guns. This new furnace has been equipped with an improved thermocouple. With this thermocouple, which is incorporated in a single tube, it is possible to determine temperatures at the center of either end of the furnace, also to make differential determinations for any combination of the three points. The set-up, in general, is a decided improvement over earlier arrangements for the work. The shape of specimens used in expansion measurements has been modified to eliminate all possibilities of errors

due to rust or blisters forming between the specimen and the drop wires at high temperatures.

Length Testing.

The following table gives a summary of the thermal expansion tests made during the year:

Materials.	Number of Samples.
Aluminum-copper-magnesium alloys	2
Zinc-aluminum alloy	2
Bakelite, continental	1
Bakelite, dilecto	5
Bakelite, micarta	2
Condensite	3
Formica	4
Copper alloys	61
Molybdenum	1
Nickel steel	4
Tile	1
Verilite	2
Porcelain	17
Marble	3
Silicon steel	1
Steel	4
Steel (machine gun)	2
Total	115

Six aluminum alloys tested in cooperation with the Metallurgical Division were under consideration as possible materials for airplane construction. The copper alloy work has progressed far enough to show a definite mathematical relation between the coefficient of expansion and percentage of alloying metals.

Special War Problems.

(*a*) Assistance was given the Signal Corps in correcting certain defects in the range-finding mil scale used in officers' field glasses. The Bureau also cooperated with the Navy Department in improving the quality and quantity of mil scale production at the optical shop annex. Master plates used in making the above scales have been constructed giving the ranges in meters and yards on each scale.

(*b*) A new type of direct reading micrometer gauge was designed and constructed for special requirements of the Surgeon General's Office. Values correct to one-thousandth inch are shown automatically.

(*c*) Errors in Brinell microscope scales used in testing the hardness of iron have been located.

(*d*) Computation and introduction of metric range values for mil scales.

MASS.

(The preparation of specifications and tolerances for weights and balances, improvement in design of balances, solution of fundamental problems arising in connection with weighing; examination and test of precision weights and balances and design of weights.)

Weights and Balances.

A new classification of weights, together with new specifications, and new regulations and fees for testing standard weights were put into force in December. Because of unavoidable delays in complet-

ing the new edition of Circular No. 3, this new classification and the regulations were issued in abbreviated form in a mimeographed pamphlet.

New Material for Small Weights.

In view of the present scarcity of platinum and its urgent need for other technologic work in which no satisfactory substitutes are available, this Bureau early approved the use of gold for weights of 500 milligrams and less. Since then, "rhotanium A" and "palau" have also been approved for use in sets of high-grade analytical weights, such as are included in class S of this Bureau's classification. A brief announcement in regard to these facts was sent to all makers and dealers who could be reached. The War Industries Board now refuses to release platinum for use in making such weights.

New Method of Testing Weights.

In continuation of the plans for shortening the time required in the testing of ordinary analytical weights there was purchased a high-grade assay balance equipped with a device by which a special set of weights can be applied from without the case. On account of certain defects which developed in this balance, the method was not at first wholly satisfactory. The difficulties in details have now been largely overcome. It appears that the method will ultimately succeed in saving a considerable amount of time.

Routine Weight Testing.

Testing of this character carried out during the year was somewhat less in amount than during the preceding year. Standards were tested for six States and for a number of different offices of the Federal Government. The latter include the Ordnance Department and the office of the Surgeon General of the Army, the Director of the Mint. the Bureau of Mines, the Bureau of Ordnance and the Office of Inspector of Hull Material of the Navy Department, and several others. An increasing amount of work has also been done for other divisions of the Bureau.

TIME.

(Origin and improvement of methods of test, and the testing of watches, clocks, and chronometers, and preparation of specifications therefor.)

Time-Measuring Devices.

The work of the Time Section has increased very greatly over that of the previous year. The increase has been primarily due to the requirements of the United States Shipping Board for ship watches, or high grade watches of proved quality to be used on ships of the Emergency Fleet in place of marine chronometers, which are unobtainable in the numbers required, and for ship clocks, and to a demand by the Ordnance Department, United States Army, for accurate stop watches.

On account of this urgent war work the regular class A tests scheduled for August, 1917, and each succeeding three months were canceled, only one test for this class of watches being held during the fiscal year. This was begun on April 25, with 25 watches submitted.

A summary of the year's work follows:

	Number tested.
Class A watches	25
Researches for Government Bureaus	52
Researches for Time Section	7
Ship watches	553
Ship clocks	745
Airplane clocks	71
Stop watches (precision test)	4
Stop watches (ordinary test)	3,743
Miscellaneous tests	2
Total	5,202

Of the 25 watches submitted to the class A test, certificates were granted in the case of 9, all of which were of American make; certificates were refused in the case of 15 watches, of which 3 were of European and 12 of American make.

Continuous assistance in an advisory capacity was rendered the United States Shipping Board throughout the first part of the year in the purchase of navigation instruments. This included the preparation of the major portion of the specifications for ship watches. The Bureau also assisted in preparing specifications for certain airplane watches.

During the year a number of Government Bureaus submitted specifications for timepieces for test, and asked for reports on their performance, with a view to drawing up suitable specifications. Recently the Bureau has been asked to prepare specifications for factory tests of timepieces and to do "calibration testing" as a key to the performance in special phases which are not included in factory tests. The outlook is very encouraging for a wider application of the Bureau's specifications and a greatly increased use of its facilities for testing timepieces.

CAPACITY AND DENSITY.

(Design and improvement of apparatus and methods of test, preparation of specifications for, and testing of glass volumetric apparatus, capacity measures and hydrometers, measurement of density and thermal expansion of liquids, density of solids.)

Capacity and Density.

The following is a summary of the volumetric apparatus tested during the year:

	Number submitted.	Number rejected on preliminary examination.	Number tested.
Metal capacity measures	140		140
Burettes	275	20	255
Cylindrical graduates	69	5	64
Dilution pipettes	438	11	427
Flasks	560	216	344
Transfer pipettes	643	114	529
Measuring pipettes	94	4	90

Of the volumetric apparatus submitted for test 60 per cent passed the test, while of that actually tested 72 per cent passed.

One thousand three hundred and nineteen hydrometers were tested, an increase of 35 per cent over last year. Sixty-seven per cent

of the hydrometers submitted passed the test, while of those actually tested 71 per cent passed. In addition 1,100 sugar flasks were tested, 100 miscellaneous tests were made, and the work of inspecting and testing a lot of 216 cylindrical graduates is well under way.

Two hundred and twenty-four density determinations were made on various substances, representing an increase of 45 per cent for the year.

Density Researches.

Density determinations were made on several samples of sea water and other sodium chloride solutions in cooperation with another section of the Bureau. The data obtained in this work will be useful in problems of oceanography. Several samples of sodium chloride solutions of various concentrations have been prepared for the completion of an investigation on the density-concentration relation and for the purpose of establishing a percentage scale for salt solutions for use in the manufacture of hydrometers to be used in the pickling industry.

During the year several firms interested in the manufacture of dilution pipettes sent representatives to the Bureau for conference and information on our method of testing such pipettes. The dilution pipettes recently submitted show an improvement over those submitted in the early part of the year, indicating that the manufacturers are producing a better grade of pipettes.

Several of the manufacturers of other glass volumetric apparatus have visited the Bureau and spent some time in studying our methods of testing volumetric glassware.

GAS-MEASURING INSTRUMENTS.

(Design and improvement of apparatus, and the investigation and improvement of methods of tests of gas meters and meter-proving apparatus and other instruments used in connection with the flow of gases; testing of meters and meter-proving apparatus.)

Gas Measurement.

The gas-measuring section has made tests of six dry gas meters for use in war work by different branches of the Government and furnished information and advice from time to time regarding the measurement of gas in small and large quantities. The improved type of portable cubic-foot apparatus for calibration work, developed by this section, has been used in the investigational work of the Gas Warfare Division of the Army, and a considerable number of these instruments have been constructed for this purpose.

This section has cooperated with different branches of the naval and military service with considerable success, a part of this work being of a confidential nature.

WEIGHTS AND MEASURES LAWS AND ADMINISTRATION.

(Cooperation with States in the administration of weights and measures laws; promulgation of specifications and tolerances for apparatus, and of rules and regulations; enforcement of standard barrel laws; conducting weights and measures investigations; annual conferences of State and local officials on weights and measures.)

General Weights and Measures Legislation.

Several States have enacted amendments strengthening their code of weights and measures laws during the past year. No national weights and measures legislation has been passed, but there is now

before Congress a bill designed to standardize packages of flour, which has the hearty support of this Bureau and also of the milling trade in general. By the terms of this bill the 100-pound package is made the standard, and all other packages are required to be a multiple of 100 pounds, or one of the following fractional parts thereof, viz, 50, 20, 10, 5, 4, 2, or 1 pound. This bill eliminates the present odd-size barrel of 196 pounds and its subdivisions, 98, 49 or 48, 24 or 24½, 12 or 12⅛ pounds, etc. It therefore simplifies the package units very much and provides for uniform packages throughout the country, a condition which does not exist at the present time on account of conflicts in State laws and of the customs of trade.

Cooperation with States and Other Interests in Weights and Measures Administration.

This feature of the work, which has proved to be of the greatest utility in obtaining the proper and uniform enforcement of weights and measures laws in the past, has been continued in so far as possible during the present year. While it was deemed advisable again to postpone the session of the annual conference on weights and measures on account of congested conditions on the railroads and in Washington and on account of the greatly increased work devolving upon the bureau staff and upon State and local officials on account of the war, assistance has been rendered in other ways whenever practicable. Representatives of the bureau have attended State conferences in Indiana, Maine, Massachusetts, New Jersey, New York, West Virginia, and Wisconsin and have given instruction on subjects of current interest and importance, particular attention being paid to the standard barrel law, which will be enforced largely through the aid of State and local officials. Assistance in solving special problems, such as installation of State weights and measures laboratories and difficulties arising in connection with obtaining and maintaining accuracy in oil pumps and gas, water, and electric meters, has been furnished both at the bureau and in the field and by correspondence. A publication entitled "Manual of Inspection and Information for Weights and Measures Officials" has been completed and is now in page proof. This should do much toward improving and unifying practices among the various departments throughout the country. Many requests for copies have already been received.

In its work of cooperating with other interests representatives of this Bureau have contributed to other conferences and meetings, among which may be mentioned, in addition to those referred to above, the National Scale Men's Association, the American Society of Mechanical Engineers, where war problems were particularly presented and discussed, and a meeting in Cleveland to discuss the matter of specifications for structural steel for the bridge construction of railroad track scales.

COMMERCIAL SCALES.

(The testing of railroad track scales, elevator scales, mine scales, other commercial scales and weighing and measuring apparatus; specifications for and capacity rating of scales.)

Preliminary Mine-Scale Investigation.

In August, 1917, it was brought to the attention of the Bureau that a serious condition of affairs existed in the coal fields of Alle-

gany County, Md., as a result of disputes continually occurring between the miners and operators in regard to the condition of the scales and methods used in weighing the coal mined by the workers, upon which their wages depended. The miners distrusted the weighings obtained from the scales in use and believed that they were not receiving the full amount of pay to which they were entitled. No method of remedying the situation had been found and it had become so acute that a general strike was impending and would certainly have occurred had not the Bureau promptly intervened and obtained a postponement of this action while an investigation was conducted. This matter was considered to be of the greatest importance on account of the special necessity for continued production of coal at this time, when it is so vitally needed.

No attempt was made to test all the scales in the region, those being selected for test at mines where the friction between operators and employees was most pronounced. As a corollary to the test of scales an investigation was conducted into the matter of average tare weights and others matters closely related to the accuracy of the weights obtained.

It was demonstrated that the grievances of the miners were in many cases well founded. The scales had in many instances been improperly installed, and, again, no proper attention to their maintenance had been given throughout long periods of service. Again, in at least one instance fraud in weighing was very strongly indicated. The result of all these conditions was that very serious errors of use were common—not a single scale examined being within the tolerance allowable in such work; moreover, important errors were in every case in favor of the operator. One scale used to weigh loads of less than 2 tons was out of balance by the extraordinary error of 616 pounds, and one of the counterpoise weights used thereon was in error by 111 pounds on a nominal weight of 1,120 pounds, both errors, of course, resulting in underpayment of the miners for the coal dug by them. In another case two counterpoise weights were found which had been plugged with lead in such a way that errors of 103 pounds and 41 pounds were introduced, the total error on the scale, including other causes, being 166 pounds, this discrepancy again resulting in short weight. Other errors were consequent upon faulty methods of operation, such as the incorrect determination of tare weights of cars.

The representatives of the bureau were called before the Allegany County grand jury and gave testimony regarding the results of the inspections and tests, and later, indictments having been found, testimony was given in court. In the cases of three scales fines of $300 and costs were imposed in each case, while in a fourth case sentence was suspended upon the company's action in paying to their workers more than $2,200, which had been wrongfully withheld on account of the inaccuracy of the weights.

As a result of the above-described circumstances an urgent deficiency appropriation of $15,000 was granted by Congress for the continuation and broadening of the scope of the work. Also certain changes recommended in the State mining law by the bureau were incorporated in a bill introduced in the State legislature. While this bill failed of passage, it is understood that many of the proposed

changes were adopted by mutual agreement of the operators and miners. Assurances were given by the companies to the court that attention would be directed to the immediate repair of all scales owned by them in this region and that such scales would thereafter be properly maintained to guard against the recurrence of errors.

Continuation of Mine-Scale Investigation.

When the appropriation for the continuation of the investigation became available steps were taken to build up an inspection force and equip them for efficiently carrying on the work. Two motor trucks of the light aviation type built in accordance with Signal Corps specifications have been procured through the cooperation of that branch of the service for transporting the personnel and equipment required.

During the last month of the fiscal year the investigation has been renewed, the same region being chosen for its inauguration, and the same method of selection of scales being adopted as in the preliminary work.

It has already been demonstrated beyond all doubt that the investigation has been productive of beneficial results, since the conditions here are on the whole enormously better than those which obtained at the time of the preliminary investigation. A general awakening to the necessity of maintaining accurate weighing equipment and properly using the same is evidenced throughout the whole region. Less dissatisfaction appears among the miners than formerly, and they show entire willingness to abide by the decisions of the Bureau.

During the later phase of the investigation it developed that about 45 per cent of the scales tested were installed or repaired in the time intervening between the two visits of the Bureau inspectors. This is a great contrast to former conditions, since at that time nearly all of the scales had been in use for years practically without attention. Thirty-seven per cent of the scales thus far tested have been found to be within the tolerance allowed and the average error and the average shortage on those found incorrect are only about one-third and one-fifteenth respectively of the former figures. Moreover, only about one-half of the incorrect scales are now in favor of the operator, while in 1917 two-thirds were in this condition, and, as stated, the average magnitude of the errors has been materially decreased.

The following shows in brief tabular form the conditions found in this region in the investigations of 1917 and 1918, respectively:

	1917	1918
Per cent of incorrect scales operating in favor of miner	33	53
Per cent of incorrect scales operating in favor of operator	67	47
Average error of scales operating in favor of miner, per cent	0.4	3.0
Average error of scales operating in favor of operator, do	9.3	1.7
Average error of all incorrect scales, do	7.5	2.4
Average shortage of all incorrect scales, do	7.4	0.5

While conditions have greatly improved, the fact can not be overlooked that some of the companies are still maintaining grossly inaccurate scales (one was found which had an error of 350 pounds on a ton in favor of the operator); inaccurate average tare weights are

in use in some cases, and faulty methods of weighing (such as weighing cars in motion, coupled cars, etc.) are occasionally encountered. The county authorities plan to prosecute in all those cases where errors are such as to warrant that proceeding.

While it is probably true that improvements thus far caused are limited to the one district investigated, it may be said that the bettering of conditions here is distinctly encouraging, and it appears that, in general, conditions can be materially improved in this manner and the production of coal thereby definitely stimulated throughout the country.

Railroad Track-Scale Work.

The investigation of railroad track scales and railroad weighing throughout the country has been carried on by the Bureau since 1913. In this work the Bureau now has, generally speaking, the hearty cooperation of the State departments of weights and measures, railroad companies, industrial concerns, manufacturers and shippers, and weighing inspection bureaus, and is constantly receiving requests for tests from all of these sources. The Bureau's scale-testing equipments are generally recognized as far superior to any other scale-testing equipments in the country and the tests made by the Bureau are considered authoritative. As a result the Bureau in many instances is called upon to settle disputes between railroads and shippers.

The war has had a marked effect upon the railroad track-scale-testing work during the last fiscal year. This has been due to two things: First, a considerable portion of the energies of the staff has been applied to direct war problems (the nucleus of the present gauge-testing force of this Bureau was obtained from the railroad track-scale-testing staff); second, the war has altered the status and increased the importance of this work since the Government has taken over the railroads and guaranteed their revenues.

Cooperation with Railroad Administration.

When the operation of the railroads of the country was placed in the hands of the Director General of Railroads, it was immediately apparent that the track-scale work of the Bureau would be greatly enhanced in importance, since the larger part of the revenue of the roads is derived from freight charges levied as a direct result of the indications of these scales. It was the desire of this Bureau to cooperate to the fullest extent with the Railroad Administration in order that the work might be made of the maximum benefit, and accordingly an offer of cooperation was promptly made. This offer was accepted by the Railroad Administration, and Circular No. 13 has been issued by that service, under the terms of which the Bureau is authorized to make tests of any railroad scales or test cars for the purpose of obtaining necessary data and information relative to specifications and tolerances and methods of test of scales. Reports of tests are to be furnished to the railroads and the regional directors concerned.

Testing Equipments for Track Scales.

During the past year the Bureau had in operation 2 track-scale-testing equipments—test cars Nos. 1 and 2—each comprising 100,000

pounds of accurate standardized weights carried in a freight car of special construction equipped with an electric generator for the purpose of developing power for operating the machinery employed in handling the weights and in moving the cars during the test.

In April, 1918, a new scale-testing equipment, consisting of 2 weight units of 40,000 pounds and 80,000 pounds traveling upon their own wheels, was completed and put into operation. These 2 cars are designed to be operated together as one testing unit, and will be satisfactory for testing all commercial track scales when used in a region accessible to a master scale, permitting the checking of the accuracy of the weights at appropriate intervals. The acquisition of these cars makes it possible to employ the other testing equipments largely in the testing of master track scales, for which work they are particularly suited on account of their special design.

Master Scale.

Since the inauguration of the track scale work it has been realized that it would be necessary to provide a master scale to serve as a primary standard for standardizing railroad track scale test cars that would be used in turn as standards for testing railroad track scales on the various lines. Therefore some time ago a master scale was ordered; this is now complete. In connection with this and as a part of the installation of this scale a building will be provided for housing the scale and an auxiliary laboratory equipped for the calibration of test weights used in connection with the test car work, such as the 10,000-pound weights forming a part of testing equipments Nos. 1 and 2, and the 50-pound test weights supplementing the equipments, and for the standardization of test cars Nos. 3 and 4. In addition a shop will be equipped for the general overhauling of the cars which becomes necessary from time to time and to furnish a storage depot for cars and other equipment. This has become especially necessary now, since the two new test cars mentioned are standard weights traveling on their own wheels, and require frequent verification to maintain accuracy consistent with the work of this Bureau. This can only be accomplished on a master track scale.

Tests of Track Scales.

During the fiscal year tests were made in 35 States and in the District of Columbia, as follows: Alabama, Arkansas, Connecticut, California, Colorado, District of Columbia, Georgia, Indiana, Illinois, Iowa, Kansas, Louisiana, Michigan, Massachusetts, Missouri, Minnesota, Montana, Mississippi, North Dakota, North Carolina, New Jersey, New York, Nebraska, Nevada, Ohio, Oregon, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, West Virginia, and Washington.

The scales tested belonged to the Federal Government, State governments, railroads, and industrial concerns.

Master track scales	16
Scales owned by railroads	291
Scales owned by industries	276
Total number of scales tested	583

Forty-two per cent of the track scales owned by railroads and 36 per cent of the track scales owned by industries passed the Bureau

tolerance. This tolerance is based on a maximum allowable error of 200 pounds in weighing a car of 100,000 pounds gross weight. Only 25 per cent of the railroad master scales tested were found to be within the tolerance adopted by the Bureau for scales of that type.

In addition to the tests of railroad track scales and master scales the Bureau's testing equipments were used in the test and calibration of 31 scale test cars owned by railroads.

Detailed reports of the tests were rendered to the owners of the scales. Copies of these reports were frequently sent to other interested parties, as, for example, officials of those States which have organized departments of weights and measures, officers of weighing and inspection bureaus having jurisdiction over scales, chambers of commerce, and the American Railway Association. Most of these reports were rendered directly by the field staff. These reports represent a very important phase of track scale work. They give the results of the test in detail, show the conditions found by careful inspection, and make definite recommendations looking to the correction of such faulty conditions as are present. It was necessary to discontinue the practice of preparing reports in the office on account of the pressure of extra war work.

The owners of the scales have been afforded every opportunity to witness and become conversant with the methods of the tests, and the recommendations included in the reports have, perhaps in the majority of cases, been carried out. In many cases new scale installations have been made, when necessary, as a result of the test and recommendations of the Bureau.

The principal deficiency in reference to the railroad track scale situation has been the great lack of master scales for calibrating the test cars necessary for the proper maintenance of railroad track scales on the part of the railroads. It is believed that when the necessary facilities have been provided for all the roads there will be a marked improvement in the design of scales installed and in the accuracy with which they are maintained. The Bureau purposes giving this matter the fullest possible consideration during the next year. At the present time there are important sections of the country in which no facilities exist for the proper test of railroad track scales, particularly those which are the property of private owners.

Consulting Work on Track Scales.

With reference to track scale specifications the Bureau has been consulted in the matter of drawing up requirements or considering bids by a number of Government agencies, railroads, and industries, among which may be specifically mentioned the Bureau of Yards and Docks of the Navy Department, the Nitrate Division of the Ordnance Department, St. Elizabeth's Hospital (a Government institution), the Virginia Shipbuilding Corporation, and the Railroad and Warehouse Commission of the State of Minnesota. With regard to the last named, specifications were prepared under the direction of the supervisor of scales governing the design and installation of railroad track scales in the State of Minnesota coming under the jurisdiction of the Railroad and Warehouse Commission, as a result of the conference between the representatives of that State and the Bureau.

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Capacity Rating of Track Scales.

In connection with the conservation of engineering effort and material and at the same time to avoid deterioration in the product, the bureau plans to make a study of the capacity rating of railroad track scales to aid the manufacturers and railroads in the procurement of weighing equipment which will be adequate for modern needs, and at the same time will eliminate unnecessary variety in the number and character of scales constructed. This work will be pushed as rapidly as the competent technical assistance can be secured.

GAUGES.

(Improvement in the design and use of munition and other gauges, origin and development of methods of test, manufacture and salvage of gauges, examination and test of gauges.)

Gauge Work.

The Division of Weights and Measures has for several years tested and standardized precision length standards and various forms of gauges and measuring instruments for the several branches of the Federal Government and for industrial concerns. In keeping with the program for the rapid production of munitions, this work has been expanded to a large degree in order to provide for the many demands made by the War and Navy Departments and by manufacturers having contracts for war material.

On June 15, 1917, a special war appropriation of $150,000 for the gauge work of the Bureau of Standards was granted by Congress, and on July 8, 1917, apparatus and equipment were transferred to a special temporary building for the testing of munitions gauges. Apparatus and personnel for testing gauges were assembled at an early date to enable this Bureau to test without delay such gauges as might be submitted. The first lot of munitions gauges was submitted on July 16, 1917.

Practically all of the various lots of gauges have been completed and shipped within three or four days from the time of receipt. In many instances the gauges were received, tested, and shipped on the same day.

The main demands which have been made on the gauge section have been the test and certification of master gauges for artillery ammunition, trench warfare material, and cannon components being produced in large quantities for the Ordnance Department of the Army. A considerable number of gauges have also been tested and certified for the Motor Transport Division of the Army, these being employed in the production of motor trucks. The Signal Corps of the United States Army also submitted during the latter part of the calendar year 1917 a considerable number of master gauges which were for use in connection with the production of aeroplanes and aeronautic instruments. In addition to the work of testing and certifying master gauges for the War Department the Bureau has received a large number of inspection gauges which were submitted by various manufacturers having Government contracts.

The organization of the gauge section includes a shop which was formed primarily for the construction of special apparatus required in the rapid and accurate testing of the more complicated forms of gauges, e. g., thread gauges and profile gauges. The per-

sonnel of this shop being mainly toolmakers and gauge makers, it has been of service in the salvage and building of gauges for exigent needs.

The gauge section has also prepared and distributed technical information pertaining to the methods of test, tolerances, tables for computation, and other essential data for use of gauge makers and gauge inspectors. Blueprints and specifications of special machines designed by this Bureau for measuring gauges have been distributed to manufacturers.

Gauges Tested.

An idea of the amount of work which has been submitted is given in the following table, which indicates the number of gauges that have been received, tested, and certified or rejected during the past year:

1917	July	244
	August	473
	September	456
	October	737
	November	1,735
	December	1,142
1918	January	2,519
	February	1,813
	March	3,582
	April	4,688
	May	4,917
	June	5,559
	Total	27,865

In the above table about 60 per cent may be classed as plain gauges (plain plug, snap, and ring gauges); about 20 per cent as profile gauges (complicated templets, chamber gauges, and fixture gauges); and about 20 per cent thread gauges. Attention should be called to the fact that of the 27,865 gauges mentioned about 60 per cent were examined for the Ordnance Department, United States Army; 15 per cent were examined for the Motor Transport Division, United States Army; about 10 per cent were on account of the Signal Corps, United States Army; and the remaining 15 per cent were examined for other branches of the Federal Government and industrial concerns having Government contracts.

In addition to the foregoing tests the bureau has been called upon to inspect at various points in the field numerous gauges used in the production of cannon. In this connection over 300 master gauges were inspected at Rochester, N. Y., for the 75-millimeter field guns, and about 500 master gauges for the 3-inch antiaircraft gun at Philadelphia. About 1,500 gauges have been inspected at the New York City branch of the gauge section of this bureau since that branch was opened on May 15, 1918.

Work of Gauge Shop.

There have been produced in the gauge shop about 50 machines for measuring screw threads and profile gauges, and various other instruments and accessories for use in connection with measuring instruments. The work of salvaging and manufacturing gauges required for immediate use was started at the request of the inspection division of the Ordnance Department about May 15, 1918. Since

that time about 400 gauges have been salvaged and in the neighborhood of 50 new gauges have been made.

Present Facilities.

At the gauge section of the Bureau of Standards in Washington there is available an organization of about 100 men for the test and certification of all kinds of munitions gauges. There are available also a shop force of about 40 men and shop equipments for gauge manufacture and salvage to the extent of over 50 machine tools. This tool-room equipment with stock accessories represents an outlay of about $100,000.

In the Branch Gauge Section at New York City there has been duplicated practically all of the various types of equipment available at the bureau in Washington for the test of munitions gauges. This branch is conveniently located in the Engineers Building at 29 West Thirty-ninth Street. At the present time about 15 men are assigned to the New York branch; this number will be increased whenever the requirements of the work make it necessary. Preparations have been made for the organization of a branch laboratory in Cleveland and one in Bridgeport. The laboratory in Cleveland became available for the test of gauges on July 1, 1918, and the laboratory at Bridgeport will be opened about August 15, 1918.

Suitable increase of facilities at Washington and at the branch laboratories will take place as fast as the needs of the War and Navy Departments and manufacturers are presented.

PUBLICATIONS AND INFORMATION.

(Publications issued on mass, length, capacity, expansivity, and cooperation with States on weights and measures; and mention of miscellaneous information on humidity, nickel steels, tonnage space, and weights and measures apparatus.)

Publications.

The following publications have either been prepared or entirely revised during the year: Circular No. 3, The Design and Test of Standards of Mass; Circular No. 10, Legal Weights (in pounds) per Bushel of Various Commodities; Circular No. 67, Wire Gauges; Circular No. 71, Rules and Regulations Promulgated under Authority of the Federal Standard-Barrel Law; Circular No. 77, Tables of Unit Discplacement of Commodities; Miscellaneous Publications No. 1, A Manual of Inspection and Information for Weights and Measures Officials; a paper on The Thermal Expansion of Molybdenum, and Technologic Paper No. 114, Portable Cubic-Foot Standard for Gas.

Miscellaneous Information Furnished.

Some information has been given regarding the measurement of humidity in the temperature range 50°–150° C., and a chart giving approximate computations has been prepared.

A number of letters have been answered giving data on expansion of materials, especially the nickel steels, concerning which there seems to be a considerable demand for information.

An investigation was made for the Post Office Department of the claims concerning a tide motor as set forth in advertising matter transmitted through the mails by a certain corporation, the object of the investigation being to give the Post Office Department a basis on which to determine whether it was permissible to send such ad-

vertising matter through the mails, under the postal laws. The bureau found that the claims made were gross exaggerations and that the motor is entirely impracticable.

During the early part of the fiscal year the bureau cooperated with the Food Administration by furnishing lists of weights and measures officials in the various States, about 1,500 in all, so that the Food Administration could enlist the services of these officials in the conservation of food, as it was believed that this body of men, in view of their acquaintance with the methods used and the channels employed in the production of food supplies and their distribution from the producer to the consumer, could render valuable service. The bureau prepared a circular letter to these officials explaining that cooperation with the Food Administration would be of great benefit and urging their assistance. The replies to these letters indicated that the fullest measure of cooperation and assistance would be given the Food Administration.

In view of the necessity of making efficient use of the full tonnage capacity of ships, the Bureau has been compiling information on the volume displacement of various commodities as packed for overseas shipment, to ascertain the number of pounds per cubic foot, the number of cubic feet of space required for a short ton and a long ton, and the manner in which the material is packed for shipment, so that the data might be compiled in a form readily usable. Information along this line has been furnished from time to time to various branches of the Government, as well as to private concerns. A short circular has already been prepared presenting much of this information and a more extensive publication is now nearly ready.

At the request of a representative of the inspection office of the Quartermaster's Department of the Army data were made available for the comparison of the accuracies in field service of two types of liquid-measuring pumps under consideration for purchase by the Depot Quartermaster Corps. The data furnished were derived from the extensive field inspection made about a year ago, which was recorded by the use of index cards in a manner making it possible easily to determine statistically the comparative merits in operation and the relative permanence and accuracy of the various makes concerned. This information when considered with results subsequently obtained in a test of efficacy of the filter with which the pumps are equipped for separation of water from gasoline provided adequate information on which to decide the purchase.

In connection with the purchase of a large number of prescription balances and apothecaries' weights for the medical supply depot of the Army at New York City, the Bureau was enabled, in view of the thorough study that it had given to tolerances and specifications for balances during the past several years, to render valuable assistance in the preparation of specifications with which the apparatus should comply and the tolerances that should be allowed. A considerable saving in time, which is always so important a factor in war work, was also undoubtedly effected.

Assistance was rendered the weights and measures department of the State of Massachusetts in preparing plans for rearranging and enlarging their laboratory to take care of expanding work, a representative of the Bureau being sent to Boston to inspect personally the available space and to confer with the State officials in the matter.

2. ELECTRICITY.

[Electromotive force, resistance, current, inductance, capacity, conductivity, insulation, magnetic permeability and hysteresis, radioactivity and radiocommunication, including researches on electrical units and standards, measuring instruments, and methods of measurement, and cooperation with standardizing committees of technical societies, with testing laboratories, the electrical industries, public-service companies, and public-utility commissions, municipalities, and engineers upon problems of electrical standardization, including standards of adequacy, and safety of electric service.]

Scope of the Electrical Work.

One of the most important functions of the Bureau with respect to electricity and allied subjects is the establishment and maintenance of the fundamental standards upon which all measurements in these fields are based, including cooperation with similar institutions in other countries so as to secure international uniformity. This includes the intercomparison of standards and extensive research in methods of measurement and the development and improvement of subsidiary and derived standards. These standards are utilized and the results of the researches are immediately applied in the testing of reference standards and instruments for manufacturers, testing laboratories, universities, research institutions, electric utilities, utility commissions, engineering and other interests, and various agencies of the Government.

The testing of electrical instruments and apparatus is of two main classes. First, there is the standardization of reference standards and precision instruments for manufacturing and other institutions which themselves make or standardize instruments for commercial use or which conduct research work. It is through the work of such institutions that the measurements made in practice are referred back to the standards of the Bureau. Second, a limited amount of testing of commercial electrical measuring instruments, radio and photometric apparatus, magnetic materials, etc., is done, chiefly for the purpose of keeping the Bureau in touch with the needs of the industries, of developing methods, and of improving types. The greater portion of this testing is done for the Government services, and serves the double purpose of providing information to be used in formulating specifications, and of determining the quality of deliveries of materials purchased upon specifications.

The research work has mainly to do with methods of measurement, the determination of the electric and magnetic properties of materials, and the development of those phases of engineering science in which measurement plays an important rôle. Electrical, radio, and illuminating engineering interests are all served by these investigations. The Bureau also renders important service, both directly and indirectly, to manufacturing and other industries. Some of this investigational work is on the more fundamental aspects of the principles involved, so that the results may be applicable to a class of problems, rather than being limited to the one specific problem under investigation. The work in measurement of lights of different colors, and correlations of magnetic and mechanical properties of iron and steel, and study of galvanometers are examples.

The research work in radiocommunication, magnetism, radioactivity, and photometry is along lines quite similar to that in the more purely electrical measurements. Standards have been and are being developed, methods of measurement are being improved, and

important special problems of significance to the industries and in a number of cases of particular importance to the Government, are being investigated. Specific examples of the projects in hand during the past year are given in the sections below.

Special Military Work in Electrical Subjects.

During the past fiscal year opportunities for service to military departments have been so numerous both in testing and in research that the resources of the electrical division, like those of other parts of the Bureau, have been very largely devoted to such service. This has involved a greatly increased amount of work similar to that performed in ordinary times, including consultation with other departments on a large number of technical problems; opportunity has also been found to undertake somewhat extensive investigations of a few important military problems. This military work has been made possible in part by the use of special funds provided by Congress and by the military departments and in part by cutting down so far as practicable the time devoted to ordinary work which has less bearing on the war.

STANDARDS OF RESISTANCE.

(Maintenance of fundamental standards of electrical resistance, calibration and development of practical resistance standards and apparatus, testing of conductors and of conductivity of materials, galvanometer design.)

INDUCTANCE AND CAPACITY.

(Methods of measuring inductance and capacity, preservation and calibration of standards of inductance and capacity, design of apparatus involving inductance and capacity phenomena, development of formulas for computing inductance and capacity, measurement of short time intervals.)

With the exception of necessary work in routine testing, these two sections have devoted practically all their time during this year to urgent military problems of a confidential nature.

ELECTRICAL MEASURING INSTRUMENTS.

(Design and calibration of electrical instruments and appliances.)

Testing of Electrical Instruments.

This work has necessarily been considerably curtailed during the year. Preference has been given to tests for the military authorities, but the needs of others have been met so far as possible. Work of this kind is made more difficult, but at the same time more necessary by the fact that mechanical defects and errors of calibration are more frequent now than in normal times. Even the best makers of instruments have had difficulty in keeping their output up to the usual standards of accuracy.

New Deflection Potentiometer.

Some improvements in the design of deflection potentiometers have been made, and the latest type of this kind of instrument incorporating these improvements was received from the makers early in the year. The design has been simplified as compared with former instruments. This latest potentiometer has a fundamental range of 0 to 150 millivolts readable by estimation to 10 microvolts.

Instrument Transformers.

The accurate testing of instrument transformers is of increasing importance on account of their use in measuring electrical energy,

especially where it is sold in large quantities or at high voltages. Some of the State public utility commissions now require the periodic testing of instrument transformers used in the sale of electrical energy. A very considerable amount of assistance has been given to some of the State commissions and the larger central stations in designing special equipment for their laboratories for the testing of instrument transformers. Two sets of such equipment have been constructed and submitted to the Bureau for test.

Methods of Testing the Electrical Properties of Transformer Oils.

In cooperation with a committee of the American Society for Testing Materials, a comparative study is being made of disk and sphere spark gaps for testing the dielectric strength of transformer oils. A carefully prepared schedule of tests on different gaps and different spacings is being carried out in four different laboratories. This investigation has been delayed by the pressure of war work. Some progress has been made in correlating the data obtained in the Bureau's tests and those of the Vacuum Oil Company. The Westinghouse Company has made the tests but their results have not been received by the bureau. The General Electric Company is also to make measurements for comparison with the others. It is expected that data will be obtained which will permit results obtained on one form of gap to be interpreted in terms of other forms of gaps, or possibly a uniform method of testing may be agreed upon.

Blasting Machines.

At the request of the General Engineer Depot and of the Army Ordnance Department, tests have been made of the electrical blasting machines used in firing trench mortars, mines, etc. There seems to be room for much improvement in the design of apparatus for this purpose and several experimental models have been constructed which show promise of reduction in weight and cost, and increase in reliability. Improvements have also been suggested for the indicators used to show that such machines are in working order just before firing.

Ignition in Gasoline Engines.

Investigation of problems connected with spark plugs, magnetos and other ignition devices, has been carried on by the Electrical Division in cooperation with other parts of the Bureau. Statistical records are now being kept of the plugs used in various aviation engines at the Bureau to determine their average service. These records indicate that fouling from carbon deposits is by far the most frequent trouble.

Improved porcelains, developed by the Ceramic Laboratory of the Bureau, have been put into production by at least one manufacturer and are now being tested in Liberty motors.

At the request of the Bureau of Aircraft Production oscillograms have been taken showing the performance of various types of magneto and battery ignition systems. The information contained on these oscillograph films is gradually being digested and will be incorporated in a series of reports covering various features of the operation of magnetos.

An investigation has been begun on the use of subsidiary spark gaps and condensers in various connections with ignition systems.

The phenomena appearing in such circuits are exceedingly complex but there is definite evidence that such arrangements will cause a heavily sooted plug to fire under certain conditions. There is promise of developing on this basis a practical system of great value.

Mica for Electrical Purposes.

At the request of the War Industries Board, tests have been made on a number of samples of mica to determine their suitability for use in magneto condensers. A number of magneto factories were visited in connection with this work, and the methods of testing used in the factory were studied in order to duplicate as far as possible the requirements of commercial practice. The best utilization of our mica supply is of great importance because difficulty is experienced in obtaining shipments from India, which has previously been the chief source of supply.

Printing Chronograph.

For the Bureau of Ordnance of the War Department, a printing chronograph was rebuilt so that four printed records may be made simultaneously by as many observers. This instrument is for use in securing experimental data for improved range tables, and in the timing of shrapnel fuses which are tested at the Aberdeen Proving Ground.

Velocity of Projectiles.

For several months the Bureau cooperated with the Sandy Hook and Aberdeen Proving Grounds on the problem of the rapid and accurate determination of the velocity of projectiles. A representative of the proving grounds was stationed at the Bureau, and members of the Bureau cooperated with him in the preliminary laboratory study of various methods for the measurement of velocities, accompanying him on trips to the proving ground for field trials.

The method finally decided upon is now in regular use in the testing of ammunition in this country and in France. Arrangements of the electrical circuits for the recording part of the method were worked out at the Bureau. A master direct-reading scale for this work was made at the Bureau, and in use was found to make it possible to obtain final results in 10 seconds.

MAGNETIC MEASUREMENTS.

(Measurement of magnetic properties of materials; design and calibration of magnetic instruments and appliances, including compasses; magnetic analysis.)

Bismuth Spiral for Measurement of Magnetic Fields.

In many kinds of investigational work bismuth spirals are very useful, but suitable methods of calibrating the spirals have been lacking. The development of a method and of apparatus for the calibration of these spirals, has been completed during the year and a paper on the subject has been submitted for publication. The method provides a means for placing the spiral under test in a magnetic field which is measured by means of a standard test coil and ballistic galvanometer. Suitable temperature control is also provided. Numerous precautions which must be observed both in the calibration and the use of bismuth spirals are pointed out in the paper.

Determination of Magnetic Susceptibility.

Considerable experimental work has been done on the development of a rapid method for the determination of magnetic susceptibility in routine testing. Two methods have been investigated, one using a sensitive balance for weighing the attraction of a magnetic solenoid for a sample under test, and the other a ballistic method. This work is not completed but has been laid aside for more important work arising from military needs.

Standard Magnetic Bars.

A set of bars has been prepared to serve as magnetic standards. Their magnetic homogeneity has been carefully examined and complete magnetic data determined. The magnetic properties will be redetermined from time to time as a check on their constancy.

Magnetic Analysis.

For a number of years work has been under way at the Bureau in the development of methods and apparatus for using the magnetic properties of materials as an indication of their quality and mechanical properties. During this year a paper entitled "Magnetic Analysis as a Criterion of the Quality of Steel and Steel Products" has been submitted for publication. The magnetic properties which might serve as criteria for the estimation of the mechanical fitness of steel are considered in detail and some methods of testing are described. The correlation between heat treatment and magnetic properties of high carbon steel is given, as well as many other valuable data.

The general method of "magnetic analysis" has been applied during the year to the three special problems of rifle-barrel steel, ball-bearing races, and steel cable. The plant of one of the large manufacturers of small arms was visited in connection with the study of the process of manufacture of rifle barrels and special work was undertaken with a view to the development of suitable methods of magnetic testing for this steel. Promising preliminary results have already been obtained and apparatus is now in process of construction for the testing of the steel bars used, as received from the mill.

The application of magnetic testing of ball-bearing races was undertaken in cooperation with one of the larger manufacturers of ball bearings, and in this connection efforts are being made to develop a design of testing apparatus which will be suitable for use in the factory. Some preliminary experiments in the work on steel cables have been carried out, but, as in the case of the last-mentioned investigation, have suffered serious interruption on account of the transference of men into the military service.

Magnetic Compasses.

The formulation of specifications and the development of methods of testing of compasses have received little attention in the past. During this year specifications for performance of airplane compasses and of lensatic compasses have been drawn up and submitted to the military authorities. The proposed specifications for the lensatic compasses were adopted by the Engineering Bureau of the Army Ordnance Department.

Methods of testing were developed in cooperation with the Inspection Department, Equipment Division of the Signal Corps, and

cooperation with this Department is being continued. Apparatus has been constructed for compass testing at the Bureau and is still in process of development.

Investigations have been carried out on damping liquids for airplane compasses which have led to the adoption of kerosene instead of the alcohol and water mixture formerly used. Specifications were prepared for kerosene for such use. Experiments were also made on the methods of heat treatment and aging of magnets for compass needles and compensators.

Railway Signal Relays.

At the request of the Committee on Direct Current Relays of the Railway Signal Association, an investigation of railway signal relays has been undertaken. This is to include the development of a suitable aging process by means of which deterioration of a relay will be produced comparable with that which occurs in a long period of service. This process is to form part of a test procedure to be used in tests under the auspices of the Signal Association.

PHOTOMETRY AND ILLUMINATING ENGINEERING.

(Maintenance of photometric standards, calibration of standard lamps, development of methods of photometry, inspection and life-test of electric lamps, problems in the utilization of light.)

Trench Flares.

The exigencies of trench warfare call for the use of many special illuminants. Many of these are quick-burning flares of very high candlepower. Immense quantities of these materials are being purchased by the War Department, and no quantitative information about their performance was available. In cooperation with the Ordnance Department, measurements of candlepower, time of burning and smoke produced were made on samples obtained from different sources to find out what might reasonably be expected of each type of light. Similar measurements were made on many samples in order to improve the performance by modifying the composition and construction. The developmental work on these illuminants is largely chemical and has been handled by the Ordnance Department. The Bureau has developed methods of making the photometric tests required and has assisted the ordnance officers in initiating the work of routine inspection and testing.

Portable Acetylene Lights.

Several months were spent in a test of numerous types of portable acetylene lights with particular reference to their suitability for military use at the front. These tests were made primarily to obtain information which should serve as a basis for choice between the different types of light. It developed, however, that nearly all of them had certain defects for such use. The defects of various types were discussed with the makers and a number of modifications suggested by the bureau were made.

At the request of the Signal Corps, comparisons were also made between two types of acetylene generators for use in traveling photographic workrooms. After tests were made in the Bureau laboratories, the development of improved apparatus was taken up with the manufacturers and as a result a satisfactory outfit much simpler than that now in use is nearly ready for production.

Photometric Tests of Field Searchlights.

This work has included field measurements and laboratory tests. The field work has been largely the measurement of illumination in the beam at various distances up to 4 miles, with particular reference to the distribution of the light from different types of searchlights and to the effect of front glasses, louvers, various reflectors, and various types of carbons. The laboratory measurements have included determinations of the intensity and distribution of the light from the arcs (without reflectors) under various conditions.

Special Problems in Illumination.

Numerous conferences on illumination problems have been held and many minor tests made for various departments of the Government. A great deal of this consultational work has been done for different sections of the Science and Research Division of the Signal Corps, for whom at various times more than thirty lamps have been standardized or measured under special conditions. Besides these a number of tests of lamps at excessive overvoltages have been made in order to determine the best condition of operation for tracing by photographic methods the course of falling bombs.

For the Field Medical Supply Depot of the Army, a collection of flashlights were tested to determine the candlepower of the lamps and the distribution of light in the beams. A comparative life test of flashlight lamps was also carried out. This included the comparison of lamps of American manufacture with a number of samples submitted by importing firms. It was found that the American lamps in general were far superior to the imported ones.

In connection with the choice of lighting fixtures for various buildings under construction for the Government, a considerable number of samples were obtained at various times, and measurements of the distribution of the light from them were made. Several sets of samples of window fabrics for use in the war zone were measured to determine their transmission.

Standard Specifications for Electric Incandescent Lamps.

Unsettled manufacturing conditions arising from the war have made necessary considerable changes in the standard efficiencies of incandescent lamps. A new (eighth) edition of Circular 13, "Standard Specifications for Electrical Incandescent Lamps," has been prepared and issued. The most important changes are (1) a small reduction in the efficiency of vacuum tungsten lamps, necessitated by unfavorable manufacturing conditions, (2) the addition of specifications for gas-filled tungsten lamps, and (3) a provision for small readjustments of efficiencies downward as well as upward at the request of the manufacturers. Previous specifications have allowed increases of efficiencies but not decreases.

Inspection and Life Testing of Lamps.

As a result of war activities, the Government's purchases of electric lamps have multiplied several fold. Orders placed during this year call for about 8,500,000 (5,350,000 large tungsten, 1,450,000 large carbon, and 1,700,000 miniature lamps), and inspection by the Bureau was requested on about 5,800,000 of these. Production has lagged behind this great increase in orders and about 2,800,000 of the above lamps were undelivered on July 1, 1918. Actual inspections

during the year, including lamps delivered on orders placed last year, approximate 3,700,000 lamps, of which about 1,100,000 were carbon and 2,600,000 tungsten. Life tests were completed on 2,015 tungsten and 559 carbon lamps. A new detail in the method of keeping records and reporting results is that samples have been marked to indicate the month of manufacture, and separate records of the product of each month at each factory have been compiled. This enables the Bureau to judge more fairly the average quality of the yearly output and also gives data which are useful as checks on current factory life-test results.

While gas-filled lamps have not been covered by the specifications in force during the year, a considerable number of them have been subjected to life tests for our information. In general they have shown a satisfactory performance.

With regard to the value of the routine inspection of lamps, it may be said that while the percentage of lamps rejected on inspection at the best factories is low (about 3 to 6 per cent), there is incontrovertible evidence that orders which are to be inspected receive special attention and that lamps which fail on inspection are applied on orders which are not to be inspected. Moreover, it is generally granted by factory men that the inspection is a continual stimulus to them to exercise all possible vigilance to keep the product up in quality.

Gas-Filled Standards of Spherical Candlepower.

Experience during the past year has shown that gas-filled lamps of special construction give very good service as standards of spherical candlepower. Following the Bureau's investigation of methods of comparing these lamps of high efficiency and large candlepower with the older standards, several groups of the newer lamps have been very carefully calibrated to serve as reference standards at the Bureau, and a large number of these lamps have been calibrated for various other laboratories during the year.

Automobile Headlight Specifications.

On account of the widely different regulations adopted by various States and cities for the control of automobile headlights, it has appeared desirable for the Bureau to make a study of this subject in the hope that it might assist in obtaining the adoption of more uniform regulations. Accordingly complete information regarding regulations which have been adopted has been collected, and samples of many devices which are intended to fulfil the requirements of the various regulations have been obtained. Measurements of the distribution of the light from many of these devices have been made.

A special committee of the Illuminating Engineering Society having been appointed to formulate specifications for head lamp devices, it appeared best for the Bureau to cooperate with this committee. Representatives were accordingly sent to assist in several road tests of such devices. As a result of these tests, general specifications covering the allowable and required intensities of head lamps have been formulated by the committee, with particular reference to a recently enacted law of New York State, and these specifications have been adopted by the Secretary of State of New York as a basis for the approval or disapproval of devices submitted to him. In case of dis-

pute as to the results of tests made under these specifications, provision is made for appeal to the Bureau.

RADIO COMMUNICATION.

(Methods of measurement at radio frequencies; design and calibration of radio instruments.)

New Radio Building and Equipment.

A new annex to the Electrical Building, which will be used by the radio section of the Bureau and also afford quarters for laboratories for the Army and Navy, has been nearly completed. A large amount of new equipment has been designed and ordered, and it is hoped that greatly improved facilities for the radio work will be available early in the coming year.

Circular on Radio Instruments and Measurements.

The theory and practice of radio communication have advanced so rapidly in the past few years that satisfactory text books are not available. The need of such text books for use in the Signal Corps training courses has been very urgent. To meet this need the Bureau has prepared a circular (No. 74) entitled "Radio Instruments and Measurements," which has met with a very favorable recognition and is now in use in the training courses mentioned. About 4,000 copies have been distributed.

Use of Closed-Coil Antennas.

For several months considerable experimental work was carried on in the field, in cooperation with officers of the Signal Corps, with closed-coil antennas or loops for transmission, reception, and direction finding. With the results of this work as a basis further study is being made of the apparatus by the Signal Corps, with a view to its practical application. In connection with this investigation of closed-coil antennas several interesting characteristics of such coils have been developed, and further studies of the theory and practical application of this type of antenna are planned.

Insulating Materials for Radio Apparatus.

An important investigation was undertaken early in the year involving the study of various kinds of insulating materials used in the construction of radio apparatus. Various properties of these materials were measured in other laboratories of the Bureau; the principal measurements made in the radio laboratory were those of phase difference and voltage properties. Preliminary results have been furnished to the War and Navy Departments and should have an important bearing on the production of radio instruments.

Miscellaneous Testing, Calibration, and Designing of Radio Instruments.

A great deal of testing and calibration work has been done during the year for various branches of the War Department, and in several instances designs of apparatus have been turned over for the use of the Signal Corps. For example, the standard variable condensers developed by the section have been adopted for use in the Signal Corps laboratories. Standard high-frequency resistance units have been constructed and supplied to the Signal Corps, and a standard inductance constructed in accordance with the design developed at

the Bureau has recently been requested for the Little Silver laboratories. It has been necessary also to supply full calibration data for all of this equipment, some of which required considerable experimental work. Many wavemeters, decremeters, condensers, resistance units, grid-leaks, vacuum tubes, and other miscellaneous pieces of equipment have been calibrated for various branches of the War Department.

A small portable decremeter for field use was designed, and several instruments of this type were calibrated for the Signal Corps after construction. A study was made of precision resistance measurements including the development of a direct reading phasemeter and decremeter. Extensive experiments were made upon the shielding effects of wire cages. Equipment was developed and constructed for producing high voltages, long and short waves, and for other special requirements of measurement work. An investigation of crystal detectors was undertaken and is still in progress.

Vacuum-tube Apparatus.

Vacuum-tube apparatus is finding a rapidly increasing application, and considerable attention has been given to the study of such tubes at the Bureau during the past year. Methods for measuring the characteristics of tubes have been developed and other experimental work is under way.

A compilation of published information regarding the theory and operation of these tubes as used in radiotelegraphy, radiotelephony, transcontinental telephony, and in laboratory measurements, was prepared by a member of the Bureau and published in book form by the Signal Corps, under the title "Vacuum Tubes—Theory and Use." It includes the general theory and description of the tubes, the mathematical theory of their operation, results of experimental research with the tubes, their use in radio reception, miscellaneous tubes and uses, and a bibliography. This book has been widely distributed among officers of the Army and Navy, and among radio engineers and others directly interested in the use of these instruments.

SOUND RANGING.

(In normal times Section 7 is devoted to a study of electrolysis and related problems. During the past year nearly all of the staff of the section have been working on various military problems, especially sound ranging.)

Sound Ranging.

A large amount of time has been given to the study of means of locating batteries and the development of new equipment for this purpose. Two members of the Bureau were commissioned during the year and sent abroad to put into use at the front the equipment developed at the Bureau. One of them, Capt. Ernest Weibel, was killed during the German offensive of March, 1918. Capt. Weibel's death interfered seriously with the plans which had been made for field trials of the equipment, but the work has been vigorously prosecuted at the Bureau, and field tests have been made at the proving ground at Winthrop, Md. The apparatus which has been developed has some features in which it excels any other equipment in use, and it is expected that sets will soon be put into use in France.

ELECTROCHEMISTRY.

(Electrochemical problems, particularly those involved in electrical batteries and electrical measurements.)

Electric Batteries.

The need of the development of specifications and methods of testing for electric batteries has long been recognized; but facilities have not been available to undertake this work. The needs of the military departments have recently become so urgent that the study of batteries has been undertaken.

Attention was given first to dry cells, and all the available information on the subject was abstracted and classified. Letters were sent to the leading manufacturers asking for information, and their replies were also abstracted and classified. Laboratory measurements on various types of dry cells were made under various conditions, and an examination of the structure of the cells was also made. In order to become familiar with the process of manufacturing cells, members of the staff visited a considerable number of factories.

As a result of this work, a circular has been prepared for publication. This includes information regarding the various sizes and kinds of dry cells, the general electrochemical principles involved, and the electrical performance of such cells. A set of proposed specifications for dry cells intended for Government use is also included. This circular has been sent to the leading manufacturers for criticism, and after discussion with manufacturers and users of the cells, will be published.

A large amount of chemical work has been done on dry cells, including the development of methods of determining the available oxygen, the total sal ammoniac, moisture, and chlorine, and also analytical methods of finding certain impurities which are frequently present and reduce the life of the cell. No chemical process for determining the difference between a good cell and a poor one has been discovered; but the chemical results run parallel to the electrical tests in that cells which are deficient in available oxygen or sal ammoniac, show comparatively poor electrical performance. It has been found that cells of the same make often differ greatly in composition, and in some cases where such variations of composition occur, the cells deteriorate very rapidly on open circuit.

On storage batteries, work is just being begun. A few plates have been analyzed, and attention is being given to the development of special analytical methods which are required for the electrolyte, because minute quantities of certain impurities in the electrolyte seriously affect the performance of the cells. Experiments have also been made on containers, particularly the celluloid used in some military batteries. Celluloid containing a strong solution of sulphuric acid has been found to liberate nitric acid which is detrimental to the storage battery. A considerable number of storage batteries are being received for test and electrical equipment for more extensive tests of these batteries is being assembled.

Two special reports have been prepared. One of these dealt with the question of obtaining American cells to replace the Hellesen cells which the British Government was purchasing from Scandinavia. This problem involved fitting a battery which would meet certain

voltage and current requirements into a limited space, provided for it in submarine mines. The second report was submitted to the Food Administration on the use of wheat flour in batteries. Wheat flour has long been used by manufacturers in the paste which is contained in the bag-type cells, and it was believed that an appreciable saving of wheat might be made by substituting other kinds of flour.

Attention has also been given to the construction of special cells to give long shelf life. A small number of cells were constructed at the Bureau for the Signal Corps for this purpose, and were found to give an unusually long life. The Signal Corps is taking steps to patent the process used in order that the Government may have free use of it for military purposes.

At the request of the military authorities, the development of a galvanic pile which would give comparatively high voltage and small capacity in a limited space has been undertaken. Three types of piles have been under development, one using lead peroxide, another manganese dioxide, and a third a simple pile of zinc and copper.

Among the batteries which have been tested, are the following kinds: Paper-lined dry cells, bag-type cells, silver-chloride cells, reserve cells, special batteries for the Ordnance Department of the Navy, special batteries for radio work, carbon-steel cells, flash-light batteries, alkali track batteries, alkali signal batteries, acid storage batteries, alkali storage batteries, and dry storage batteries. Tests have been made for the Panama Canal, the Bureau of Ordnance of the Navy Department, Naval Torpedo Station, Signal Corps, Engineer Corps, Medical Corps of the Army, the Depot Quartermaster and the Ordnance Bureau of the War Department. The total number of batteries which have been tested during the year at the Bureau is 450, while 3,000 have been tested at the military storehouses.

Miscellaneous Electrochemical Work.

Minor problems in electrochemistry have included the platinizing of electrodes for work in conductivity of electrolytes, the plating of radio detector crystals, the preparation of impregnated paper for spark recorders, testing the continuity of the enamel of large iron kettles used by the chemists of the Gas Defense Service, and assistance given to the Chemical Division in developing a new process for cleaning gun barrels.

RADIOACTIVITY AND X-RAY MEASUREMENTS.

(Methods of measurement of radio-active materials and phenomena, standardization of radium, radium preparations, and similar materials; development of X-ray equipment.)

Luminous Materials.

Both the apparatus for and the technique of the measurement of the brightness of self-luminous materials have been much improved during the year. The fifty preparations under study in June, 1917, and a few others obtained since then have been measured at intervals. The conclusions drawn from these measurements have been made available to the military authorities interested in such materials.

These materials are largely used for airplane instrument dials. Since little information regarding the brightness needed for satisfactory legibility of dials was available, the Bureau arranged to have

a number of dials of various known brightnesses examined under service conditions of illumination by members of the air service of the United States and allied nations. A better idea of the brightness desired under different conditions was thus obtained. The variation of the legibility with the size and brightness of the characters has also been studied.

The conclusions thus reached have been used, and passed on to those interested, as rapidly as obtained and are now being collated in a series of recommended specifications for luminous articles.

Regarding the permanence of luminous material under service conditions little was known. It was believed that in general, an exposure to direct sunlight markedly decreased the brilliance of applied material. Observations made during the past winter have, however, shown no very marked decrease in brightness, due to an exposure either to the sun or to a mercury arc. The dials used in this test were of low brightness. Similar tests upon other dials will be begun at once.

Specifications for luminous markings upon airplane dials have been recommended to the Signal Corps, United States Army, the Bureau of Steam Engineering, United States Navy, and informally to other departments of the Government. These specifications have been in the main adopted by the Signal Corps.

Since September, 1917, the brightness of a large number of dials has been measured for the Science and Research Division of the Signal Corps, United States Army), (recently transferred to the Bureau of Aircraft Production), as a basis for the awarding of contracts for the illumination of airplane instruments.

At the request of the Inspection Department of the Signal Corps, the Bureau has prepared and standardized equipment for factory inspection of dials, and has instructed inspectors in the details of factory testing. Since this equipment has been in use, brighter dials have been secured.

Since the first of January, 1918, a percentage of the luminous dials accepted by the Inspection Department has regularly been sent to the Bureau for careful measurement of brightness. Certain of the dials have been submitted to a life test, and a number of compass cards have been measured both dry and submerged in kerosene. The effect of continued immersion in kerosene also has been studied. The cause of some of the changes observed on immersion is still not clear; the study is being continued.

An investigation of methods for applying luminous materials to dials and other objects was undertaken late in November. Luminous materials were obtained from the different manufacturers and were applied to dials by means of various adhesives and methods. The various characteristics of the different adhesives and methods were noted and the brightness of the finished product was measured. The problem was studied from many angles and a method of application that is more efficient than any now in use was developed.

The following reports have been issued: "Self-Luminous Materials Containing Radioactive Excitants," "Notes and Suggestions Concerning Luminous Instruments," "Self-Luminous Materials—Brief Notes Covering a Few Points of Practical Importance." All of these were typewritten reports issued in editions of a few copies

each and have been distributed to those Government departments that have appeared to be most interested.

Throughout this work the cooperation of the manufacturers and users of these materials has been most gratifying and of great assistance to the Bureau.

Standard Radium Solutions.

Incidental observations indicate that the standard radium solutions made up in the summer of 1914 have not changed by as much as 1 per cent since they were prepared.

During the year, 100 cubic centimeters of the dilute solution (10^{-8} gram of radium per cubic centimeter of solution) were furnished to McMaster University, Canada.

Radium Emanation Work.

The work involving radium emanation measurements is mainly the examination of materials suspected of radioactivity, of waters (natural and artificial), and of therapeutic preparations. No steps have been taken to encourage the development of this branch of the work, because all the facilities available could be used to advantage in more urgent lines.

During the year 1 activator has been tested, the study of 4 others has been completed, and 5 radium determinations have been made; 2 of the latter were for the Department of Agriculture.

Gamma-Ray Measurements of Radium.

In July, 1917, the Bureau of Mines donated to the Bureau the tube containing about 49 milligrams of radium which was loaned to the Bureau of December, 1916, and also a second tube containing about 91 milligrams. Further than this, no change has been made in the equipment for this work.

Early in 1918 the rate of receipt of specimens for gamma-ray measurement decreased markedly and has remained low. The amount of material for certification to physicians is now very small on account of war conditions.

During the year 177 specimens, containing a total of 5,376 milligrams, have been measured. Of these, 50 specimens containing a total of 1,009 milligrams were certified for foreign shipment. These were distributed as follows:

Country.	Number.	Milligram radium.
France	24	651.55
Japan	11	207.19
Spain	12	129.55
India	3	20.38

Most of the radium certified for export to France is said to be for the use of the French Government in the manufacture of self-luminous material for war purposes. Two tubes (74.1 milligrams) were certified to the American Red Cross Society; it was understood that these were intended for the Russian Government.

X-Rays.

The X-ray equipment purchased in the spring of 1917 was installed in July. The apparatus has been studied in some detail, subsidiary equipment has been constructed and purchased, the routine testing of protective materials has been established, and miscellaneous radiographs have been taken for the purpose of obtaining information regarding the internal structure of materials and articles.

In its endeavor to secure the domestic manufacture of improved protective materials, the Bureau met with splendid cooperation on the part of the manufacturers. As a result, one can now obtain commercial material which gives nearly twice as much protection per unit thickness as was given by material obtainable a year ago. (Improvement in glass reaches 80 per cent, in rubber 100 per cent.) A note on this work has been published in the American Journal of Roentgenology, and a more detailed paper has been prepared for the same journal.

A study of the technique for the radiographic detection of flaws in aluminum and in steel is still in progress.

PUBLIC-UTILITY STANDARDS.

Public-Utility Investigations.

A large and important field of work, including more of engineering and field work than most of the electrical work so far described, is concerned with the various public utilities, particularly electric light and power, gas, street railway, and telephone companies. The work includes (1) scientific and engineering research, (2) the study of public-relations questions, (3) the preparation of specifications regarding the quality of public-utility service, (4) methods of testing and inspection employed by municipalities and commissions, (5) safety rules for use by the utility companies to safeguard their employees and the public, and (6) the collection and distribution of information by published papers and through correspondence.

This work is a natural outgrowth of the research and testing work done by the Bureau of Standards for the public-utility companies for several years. The testing of electrical instruments and meters, of gas lamps and the standards employed in measuring the candlepower and heating value of gas, the life testing of electric lamps, the testing of instruments used in telephone work, research on electrolysis mitigation, and similar investigations and tests connected with the public utilities have all involved to a greater or less degree questions of standards of service in the various public utilities. The bureau has gradually accumulated a considerable amount of information on these questions and has been able to contribute materially to the establishment of standards of quality of service in several of these services. Furthermore, it has promoted with marked success the practice of settling disputed questions in this field on the basis of sound engineering and economic principles and of cooperation between interests rather than by legal controversy, and in so doing the bureau has attained an enviable position as an impartial mediator in such questions. Consequently, during the past year, when abnormal conditions have given rise to many cases in which readjustment of service standards or of rates has been called for, the public-utility staff of the bureau has been called upon for an im-

possible amount of work. The opportunities for serving the public have been great and good service has been rendered. The provision by Congress of additional funds for this work by a special appropriation has made possible considerable additions to the staff toward the close of the year, and it is hoped that even more may be accomplished during the year. The work of the following sections is largely in connection with public-utility problems.

Relation of the Bureau to Municipalities and Public-Service Commissions.

In many States the public-service commissions have set standards of service, and the Bureau has cooperated with most of those that have done so. In other States the railroad or public-service commissions have taken no action in the matter, although having authority to do so. Again, in some States there are no public-service commissions to issue regulations or to inspect the quality and safety of the service rendered by the various utilities. In any case the cities and towns must look after their own interests, in whole or in part, and frequently have taken up such matters very successfully. Even where there are well-equipped and active State commissions, which have adopted rules and are ready to hear complaints regarding rates or service, a very large responsibility rests upon the municipalities. Few State commissions will ever be likely to have a force of engineers and inspectors large enough to enable them to take the initiative in every case and relieve the municipalities of all the responsibility. On the contrary, if the municipalities are active and enterprising in their own behalf, and if the larger ones have well-equipped public-utility departments which can prepare the city's complaints or requests and take them up to the State commissions for hearing and adjudication, the State commissions will be better able to serve all the municipalities of the State, and the municipalities will enjoy in large measure the advantages as well as the responsibilities of home rule without its greatest disadvantages.

But for most cities and many commissions it is a difficult matter to judge the quality of service rendered by its utilities. The studies made by the Bureau are a great help in this connection. but much remains to be done. It will conduce to fairness and a good understanding to have the subject studied further and to have specifications as definite and complete as possible made available for all branches of public-utility service.

Obviously, it will never be practicable for any State commission or city to handle these questions alone. Though they possess large and able engineering staffs or employ specialists for each separate problem, the question of what is good service or whether the service in any given case is adequate, safe. and satisfactory can be settled only by reference to what is done under similar circumstances elsewhere in the country. In other words. standards of good practice and good service are largely determined by general experience and should be studied comparatively, using the experience of the entire country. The Bureau has been doing this for several years. and although it has not been able to do as much as it would have liked to do. it has done enough to demonstrate the practicability and acceptability of the method. The success and approval which the work has met so far fully justify its greater development.

GAS ENGINEERING.

(Standards of gas service; efficiency and economy of manufacture and distribution of gas; studies of gas utilization; by-product fuel processes and related tests.)

Gas-Service Standards.

During this year the bureau has participated in important cases involving adjustment of standards for gas service before the New Jersey Board of Public-Utility Commissioners and before the First District Public-Service Commission of New York. A report was also made to the Indiana Public-Service Commission on the revision of standards for gas service contemplated for that State, and comments have been given to the Oregon Public-Service Commission on a petition relating to a change of standards in Portland, Oreg.

In the city of Cleveland assistance was given in establishing a testing laboratory, in calibrating equipment for it, and in instructing the chemists who were to carry on the routine testing. This work also included a very brief consideration of the adequacy of the natural-gas supply. At the request of the Railroad Commission of Georgia a study of gas-service conditions in Atlanta was made. It developed that the principal cause of dissatisfaction with the service was a shortage of oil for the manufacture of water gas. The bureau's report was accepted by the State commission as the basis for its decision in this case.

The shortage of supplies of oil has led to the suggestion that changes should be made in standards for gas quality, and it has been suggested to the Fuel Administration that all existing standards of heating value be abrogated and a uniform requirement of 528 British thermal units per cubic foot should be adopted. The bureau, in common with most State and city authorities, has felt that this radical change is of doubtful wisdom and has given considerable attention to alternative methods of meeting the situation without such a general reduction in the quality of all manufactured gas.

This and numerous other cases in which readjustments of standards of quality have arisen during the year have given rise to opportunity for a very extensive application of the results of the experimental work carried out last year upon the relative usefulness of different qualities of gas.

Natural-Gas Service.

As mentioned above, some attention was given to natural-gas service in the city of Cleveland. The same question was raised with regard to the supply of natural gas for the city of Louisville, and this has led to an extensive field investigation on the supply of natural gas available for this territory. Data for a preliminary report on this subject have been gathered and the cooperation of various agencies is assured in continuing this work.

Gas Lighting.

As partial reports upon the investigation of relative usefulness of different qualities of gas, Technologic Paper No. 99, entitled "Gas Mantle Lighting Conditions in Ten Large Cities in the United States," has been issued and Technologic Paper No. 110, entitled "The Influence of Quality of Gas and Other Factors Upon the Efficiency of Gas Mantle Lamps," is in press. The work reported in the latter paper gave results not in accord with the general opinion that

gases of lower heating value are much more efficiently used. The margin of advantage in utilization of such "leaner" gases is small in mantle lamps, and consequently the heating value is an excellent measure of the usefulness of the gas for lighting.

Proposed National Gas Safety Code.

The Gas Safety Code has been advanced very little during this year, but a first draft of part 2 of the code has been prepared in manuscript form. A preliminary report of tests of flexible tubing has been prepared and sent out for comment. The results obtained in these tests enabled the Bureau to render assistance to the city of New York in connection with a proposed ordinance fixing standards for the construction of flexible gas tubing. As a result the city avoided the adoption of a very drastic and undesirable form of ordinance.

Economic Importance of the National Gas Safety Code.

The Bureau of Standards in carrying out this investigation desires to serve as a national coordinating agency to the end that the resulting code will be acceptable and adequate, not only from the standpoint of the user of gas but also of the casualty and fire-insurance interests, the gas companies and their employees, and the gas-appliance manuacturing and selling interests.

The need and value of such a code is so great that the various national organizations dealing with subjects covered by the code have appointed special committees and expert representatives to assist in the investigation. The following organizations have cooperated in this work: The American Gas Institute, the National Commercial Gas Association, the Natural Gas Association of America, the National Fire Protection Association, the American Institute of Architects, the National Safety Council, and the National Association of Master Plumbers. In order that the Bureau may have the fullest information on every detail of the subjects discussed, the American Gas Institute has appointed 12 committees, four in each of the three principal sections of the country—East, Middle West, and Far West. One committee in each district is intrusted with the work bearing upon one of the principal phases of the investigation.

It has been estimated that avoidable accidents, due to ignorance, carelessness, or faulty installation result in the loss each year of hundreds of lives and the destruction of property of large aggregate value. It may reasonably be expected that many of these losses will be eliminated when the code has been completed and adopted throughout the country, both because of the official enforcement of the code and because of its educational value to gas fitters, appliance manufacturers, utility operators, and the general public.

The code will also serve to unify practice in gas installations and gas-company operation throughout the country, and it is anticipated that much-needed reforms will result. This uniformity of practice will not only tend to greater safety, but will also contribute to higher efficiency. In many cases differences between the insurance and gas-company officials can be settled by reference to the code, and thus more harmonious cooperation of the two parties can be expected. Already several important instances have been referred to the Bureau for consideration with a view to the settlement of differences in in-

surance-inspection practices or questions as to the magnitude of the fire hazard in certain types of gas installations. In this field the services of a recognized national authority are essential in order to standardize the practices and to make generally available the benefit of experience obtained in individual localities. The effort of the Bureau has therefore been directed not only to the preparation of the code but to the collection of such information as will enable it to serve as a national coordinating agency in this field.

Toluol Investigations.

Toluol has been required in large quantities for military use, and manufactured gas is one of the most readily available sources. The necessity of removing the toluol and benzol from gas has raised many questions with regard to the readjustment of standards and of the financial arrangements for carrying on this operation. Early in the year a conference to consider these problems was held at the Bureau and a committee representing State, city, and gas-company interests was organized. This committee met on two occasions for conference at the Bureau.

A report entitled "Recovery of Light Oils and the Refining of Toluol" was prepared, and after submission to the committee mentioned was circulated in mimeographed form and later reprinted in several journals. Another article on "Toluol Recovery and Standards for Gas Service" has also been published in various gas journals. There has been a very large demand for both of these papers, and a report to include both of them is being prepared.

Representatives of the Bureau have given a great deal of time in conference with the Ordnance Department with regard to contracts for the construction and operation of toluol plants in connection with city gas works.

Balloon-Gas Manual.

At the request of the Bureau of Steam Engineering of the Navy Department, a manual including a description of methods for the generation, handling, storage, and use of hydrogen for balloons and dirigibles was prepared. This manual is used for instructing the aviation personnel and as a guide in the operation and care of the balloon equipment.

Coke-Oven Investigations.

The seriousness of the fuel situation has lent particular importance to several investigations of fuel possibilities. It has been generally considered that only a small proportion of the coal deposits of the country could be used for coking, and consequently this coking coal has been hauled long distances to sections where large supplies of "noncoking" coals are available. New processes of coking have been proposed which would remedy this difficulty by utilizing the so-called "noncoking" coals. A comprehensive investigation of one of these processes was ordered by the President and carried out at the plant in Dover, Ohio, by the Bureau with the cooperation of the Bureau of Mines and the Geological Survey. The test was the most extensive ever conducted on a coke-oven process. More than 40 Government and company representatives participated in the work, which continued 24 hours a day for a period of 17 days. The results obtained in general supported the claims of the pro-

moters of the process, but final conclusions must await further tests to be made with more complete equipment in operation.

As an outgrowth of this investigation the Bureau has also had opportunity to make measurements on ovens of other types and has been asked to make a test of a different type plant to cover approximately the same ground, but more briefly than was done in the very elaborate tests first mentioned.

ELECTRICAL SERVICE STANDARDS.

(Standards of electric service; efficiency and economy of operation of power plants in the generation and distribution of electricity; street-lighting systems; central steam and hot-water heating problems.)

Standards for Electric Service.

For several years the Bureau has been studying the questions of specifications for electric light and power service, and the requirements that should be made by municipalities or by State public-service commissions of the public-utility corporations engaged in furnishing such service. This study was published last year as Circular No. 56, Standards for Electric Service.

In addition to proposed State rules and specifications for acceptance of types of meters, the circular contains three regulatory ordinances, suggested for cities of various sizes, descriptions of commissions standardizing laboratories, and a complete and exhaustive digest of State rules and of ordinances in force in various cities. The demand for this circular has been large, and it is gratifying to note that the rules, specifications, and ordinances proposed have been made the basis for State rules and city ordinances in many instances.

Even before the circular was published a few states had revised their electric service rules, and an appendix was added to include the new material. Since its publication, several new commissions have been established, the functions of old commissions changed and service rules have been revised in three States. The new laws and revised rules have been collected and are ready for inclusion in a new edition of the circular, for which the material is about half completed.

In all this work the Bureau has profited by the cordial cooperation of public-service commissions, municipalities, and public-service corporations, the National Electric Light Association, and the Association of Edison Illuminating Companies.

Standards for Street-Lighting Service.

For a year or more the Bureau was engaged in a study of street lighting in its technical and engineering aspects, with particular reference to the requirements that should be put into contracts between municipalities and public-service corporations for furnishing gas and electric street lighting. A number of municipal and private plants were inspected, photometric measurements made, and conferences held with managers and illuminating engineers.

The Bureau was receiving the hearty cooperation of municipalities and lighting companies, but the war has necessitated a discontinuance of much of the work on the part of the Bureau, and public-utility companies also find themselves unable to cooperate as fully as they would like to do. A special committee of the Edison Association of Illuminating Companies on street lighting will resume its cooperation with the Bureau at a later date.

The manuscript of a circular on "Standards for Street-Lighting Service" is partly completed. The scope and completeness of this study of street lighting are indicated by the following proposed table of contents: The purpose and problem of street lighting; the measurement and distribution of light and illumination in street lighting; lamps and accessories used in street lighting; general principles governing the design of a street-lighting system; description of typical street-lighting systems; the economics of street-lighting systems; discussion of contracts for street-lighting service; suggested street-lighting contracts; statistical appendixes.

No very active work has been done on the circular during the past fiscal year, but the digest of the literature has been kept up, new contracts obtained and additional data accumulated. Early in the year measurements were made on two types of street arc lamps to determine the distribution of the light and the variation of the candlepower and efficiency with current. This is part of an extensive program of such measurements which have been planned in order that first-hand information may be available for use in the circular.

As in the case of standards for electric service the Bureau seeks, while representing the public interest, to get the utilities' point of view also, and the study of street lighting will not be published until full discussion and cooperation can be had from public-utility corporations, technical societies, municipalities, and other interested parties.

Standards for Heating Service.

At the request of the Public Service Commission of Indiana, a study of hot-water heating service was begun and a representative of the Bureau spent about three weeks during February in Ohio, Indiana, and Illinois, visiting hot-water heating plants and conferring with their engineers. A proposed set of rules for heating service was formulated by the Bureau, and after public hearing on the matter these rules were adopted by the Indiana commission substantially as recommended. The manuscript of a circular on heating service is in preparation, and the National District Heating Association has appointed a special committee to cooperate in its completion.

ELECTRICAL SAFETY ENGINEERING.

(Study of means of reducing hazard to life and property arising from the use of electricity, in particular the development and application of the National Electrical Safety Code, and other safety codes.)

National Electrical Safety Code.

The Bureau has been engaged for 5 years in a study of the life hazard in electrical practice and in the preparation and application of the National Electrical Safety Code. In this work it has had the cooperation and assistance of a large number of engineers, many of whom are connected with the electrical operating and manufacturing companies, others being engineers and inspectors of State commissions, municipalities, and insurance underwriters. The various national associations connected with the electrical industry have also cooperated effectively in this work. The importance of having a national code uniform in all the States is realized to be quite as great for accident-prevention rules as for fire-prevention rules, and the advantage of having such a code prepared and presented by a na-

tional agency that can study the subject thoroughly and consult all the interests affected is obvious.

The Safety Code consists of four principal parts, as follows:

1. Rules for the installation and maintenance of machinery, switchboards, and wire in central stations and substations.

2. Rules for the construction and maintenance of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.

3. Rules for the installation and maintenance of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.

4. Rules to be observed by operators in working on or near electrical machines or lines.

This code does not include the matter covered by the Underwriters' Electrical Code, but it is parallel to the latter and consistent with it.

The code is intended to be adopted by State industrial and public-service commissions and municipalities and to be complied with by public-service and industrial corporations. It is also intended to be adopted voluntarily by electrical interests when the code has not been adopted by any administrative body having jurisdiction in their district.

The Bureau's thorough study of the diverse conditions under which electricity is generated, distributed, and utilized, and of the effect of the rules on operating and construction costs, has secured a code which involves no unreasonable expense, but in general assures an adequate measure of safety and a useful standardization of practice. The large number of conferences held in all parts of the country for discussion of preliminary drafts of the code aided largely in its development to the point where it was possible to recommend it for general use throughout the country. The varying conditions in different geographical sections, and in thickly and thinly populated districts, have been given careful attention.

The code was published originally in two installments for examination and criticism; the operating rules were published in August, 1914, and revised in May, 1915; the construction rules were published in April, 1915. Both operating and construction rules, again revised after a general conference of all interests in Chicago in the spring of 1916, were combined in a single volume, Circular No. 54, which was published in November, 1916, with a recommendation for actual field trial.

It has been the intent of the Bureau, as well as the desire of all branches of the industry, that the rules should be revised and extended as experience in their use and the progress of the electrical industry shows revision and amplification to be to the public advantage. The present edition of Circular No. 54 has been exhausted and a revision is now under way which will be completed before reprinting the circular. In this revision only minor changes in subject matter have been made, but there will be considerable changes in form with a view to making the code more concise and more convenient for reference. For this purpose the rules will be separated and published in one volume supplemented by separate volumes, one giving explanations of the rules and examples of their application and another engineering data which have been worked out in connection with the development of the code.

Engineering and Experimental Work in Connection with the Safety Code.

Considerable work has been done on engineering data for the construction of outdoor electrical lines, especially with reference to sags of overhead conductors. Sags have been computed for temperatures other than those used in the original published tables, and steel wires and cables have also been considered. An article on the latter subject has been prepared for publication in the Electrical World.

Experiments for determining the wind pressure upon overhead wires and the shielding effect of wires upon others where they are closely grouped have been carried out. Measurements of the pressure upon models set up in the wind tunnel have been made and will be supplemented by experiments in the open air, for which apparatus has been constructed and mounted upon the roof of the Electrical Building. The results already obtained show that there is a definite shielding effect when two or more wires lie very nearly in the plane parallel to the wind velocity. With regard to the magnitude of this shielding effect it is desired to obtain the measurements in the open air before reaching final conclusions, since it is possible that the limitations of the wind tunnel may have an effect upon the pressure.

National Electrical Safety Code in Practical Use.

The code has now been adopted in one form or another, in part or in whole, by some 20 administrative bodies, and many others have taken favorable action upon it, such as the issuance of bulletins recommending the application of the code. In a few States its application has been made mandatory, notably in Pennsylvania, Wisconsin, and Montana. The code is also being used by the inspection departments of many cities and boards of underwriters. It is being used as a basis for a merit-rating schedule by casualty interests just as the Underwriters' Electrical Code has been used by the fire underwriters for some years. Such schedule ratings should result in emphasizing both the merits and demerits of particular installations from the safety standpoint, and tend to reduce accidents by proper financial recognition of each improvement made.

The code is also being voluntarily applied by a large number of utilities and industrial concerns in their own practice. It is receiving the general approval of all these interests as rapidly as its usefulness is becoming recognized, and its advantges are seen to be greater than any minor present inconvenience which its introduction may cause. It is becoming generally understood that the stability in electrical practice provided by such a national standard also conduces greatly toward the general economy, the necessity for which is becoming emphasized during this period of national stress.

Travel and Conferences for Explanation, Application, and Development of the Code.

Since some 80 State administrative bodies and many cities have electrical departments, it is desirable to send engineers frequently to different parts of the country to assist and cooperate with officials who are considering the adoption of the Safety Code, or, as sometimes occurs, are considering the adoption of other electrical safety rules prepared locally. During the past year a considerable part of the

time of the most competent engineers engaged in the safety work has been devoted to travel and consultation with State and city authorities and others concerned. Thirty-nine State commissions have been visited and in some cases considerable time has been spent in assisting these commissions to reconcile the views of opposing interests. The code as already formulated has met with gratifying success as serving as a basis for agreement in such cases.

Scope and Application of the Electrical Safety Code.

To aid in presenting the Safety Code in cases where conference is not possible with the limited staff of the Bureau, and to assist in explaining the intended application of the code, a publication has been issued entitled "The Scope and Application of the National Electrical Safety Code." In this are included brief summaries of the different parts of the code, reasons for the character of treatment employed, some discussion of the measures taken to secure adequacy and reasonableness, and some recommendations for the method of conducting inspections of installations to secure compliance with the Safety Code provisions. The publication also contains descriptions of a number of typical accidents, repetition of which would largely be prevented by observation of the National Safety Code rules for construction and operation.

An index to the code has also been published.

Use of the Code in Educational Institutions.

A special effort has been made during the year to bring the code to the attention of technical schools, and as a result, a number of engineering colleges have decided to make use of the code in their courses during the next college year. Twenty-five schools will use the code as a part of the required work in electrical engineering, and a number of others will use it as a reference. It is believed that this application of the code will have an important effect in the future development of electrical practice through its influence in inculcating safety ideas among the new generation of engineers.

Electrical Protection for Householders.

The Bureau has conducted a study of electrical hazards in the household and the means of reducing them to a minimum. The results have been incorporated in an illustrated electrical chapter of a circular on Safety for the Household (Circular No. 75), which has been issued during the year. In this study the cooperation and criticisms of lighting utilities and underwriters have been received, and the publication is in popular language, calculated to appeal to the understanding and interest of school children as well as to the intelligent householder.

General Industrial Safety Standards.

As a result of the work of the Electrical Safety Code and the numerous points of contact thus established with State and other authorities interested in safety work, the Bureau has been called upon to serve as a coordinating agency in promoting the adoption of uniform safety requirements in other than electrical lines.

Early in the year the United States Employees' Compensation Commission undertook a general inspection of Federal establishments from the safety standpoint. The National Electrical Safety

Code was utilized as a standard of reference in this work. Later safety engineers were appointed in the several navy yards and arsenals, and conferences of these safety engineers were held for the purpose of formulating definite safety standards for application in the Federal establishments. Representatives of the Bureau were invited to attend these conferences and the Bureau was later asked to undertake the revision and codification of the tentative rules covering mechanical safety. The National Electrical Safety Code was adopted as a standard for electrical construction and installation. The Bureau has revised the standards for mechanical safety, and the work has been largely completed, except with respect to goggles and eye protection.

The need for carrying out work of this kind upon a larger scale became at once evident, and the Bureau has now undertaken a study of all available rules covering mechanical safety, with the idea of preparing a set of codes, similar to the Electrical Safety Code, which will be available for the use of State commissions and other administrative bodies concerned with the application of such rules. Steps have been taken to cooperate with State industrial commissions, insurance interests, and technical societies in this work, as well as with other Government bureaus, such as the Working Conditions Service of the Department of Labor. A large field is opened up by this work.

ELECTROLYSIS PREVENTION.

(Study of the effects of stray electric currents and development and application of methods of reducing damage resulting from them.)

Electrolysis Problem Among Public-Utilities.

The majority of the street railways of the country are operated on the single overhead-trolley plan, with the electric current flowing into the rails through the car wheels, after it has passed through the car motors. The current then flows back to the generating station or substation by way of the tracks and earth, some of it, however, often flowing through underground gas and water pipes and the lead sheaths of underground telephone and electric-light cables, and sometimes through reinforced concrete structures. The earth conducts electricity by virtue of its moisture and the salts dissolved in it, which render it an electrolyte. Hence, when the electric current flows away from iron pipes or lead-cable sheaths, it carries away iron or lead by electrolytic action, and this in time corrodes the pipes and shortens their useful life and sometimes completely destroys them in a relatively short time. The property damage caused by these earth currents when they are considerable, affects to a greater or less degree all the public utilities.

The trouble is the more serious in places where the soil has a greater conductivity than usual, and where the conductance of the tracks is small in proportion to the current, and the distance the current travels back to the stations is relatively great. Many remedies have been proposed and tried, but no standard practice for the handling of the return current has ever been agreed upon in this country. As the electric railways have been extended and traffic has become heavier, the volume of current handled has increased very greatly, and the resulting destructive effects, which are cumulative with time, have become increasingly evident. In some cases litiga-

tion has resulted between the pipe-owning companies suffering damage and the railway companies whose current causes the trouble. But although the courts have considered the question of legal responsibility, these cases did very little to prevent the trouble in an effective and economical manner.

Economic Importance of the Electrolysis Problem.

The subject of electrolysis of underground pipes, cables, and other metal structures is one which has been given more attention in recent years than formerly, but it still does not receive the attention in many quarters that its importance deserves. When one considers the enormous value of the pipe and cable properties buried in the streets of cities and forming in many cases transmission networks between cities throughout the country, and considering further that there are very few water, gas, or lead-cable systems which are not more or less subject at some points to electrolytic damage from stray currents, it is possible to form a better judgment of the practical importance of this subject. The water and gas pipe systems of this country alone have an aggregate value at the present time in excess of a billion of dollars, and in addition to this there is a vast extent of underground lead-cable systems belonging to telephone and electric power companies and to municipalities. In addition to these vast properties in the earth, a considerable part of which may be more or less subject to electrolytic damage, there are possibilities of trouble in the case of bridge structures, portions of steel frame buildings, and piers, which are occasionally exposed to damage from this source.

While the total losses due to shortening of the life of underground pipes and cables must be considerable, such loss does not by any means represent the total annual damage due directly to electrolysis. It is well known that the annual loss due to leakage of water and gas from distribution systems is very great. It is true that only a part and probably a small part of the total leakage is due solely to electrolysis, but it is only necessary to assume that a few per cent of the total is due to the more rapid developments of leaks caused by electrolysis in order to make the total loss resulting from this cause run well into the millions annually.

In making a valuation of underground pipe systems, as, for example, in the case of a valuation to be used as the basis for a transfer of property or for rate revision, it is necessary to consider possible deterioration of the pipes due to electrolysis, since in those localities in which the pipes have suffered from electrolysis the actual physical value of the system will be materially reduced.

Inconvenience and Hazard Due to Electrolysis.

It is not alone the property loss, however, that makes the electrolysis problem one of importance. An important fact is the inconvenience to consumers of water, gas, and telephone service due to the interruption of the service when repairs are made necessary by electrolytic damage. Possible interruption of the service of police and fire-alarm systems is also one of considerable importance to almost every municipality.

Wherever currents are permitted to flow on the underground pipe systems there is the possibility of electric arcs being formed when

pipes are disconnected, or when different pipe systems make momentary contact. Accidents of this kind are rare, but they have sometimes occurred, resulting in the loss of life and a considerable damage to property. Cases have occurred also in which leakage of gas resulting from electrolytic corrosion of the pipe has given rise to explosion with disastrous results. Many gas explosions in basements and manholes have occurred, and although it is difficult to determine what proportion is due to electrolysis, undoubtedly some of them are due to this cause.

A water-pipe line weakened by electrolytic corrosion may even present a fire hazard much greater than would result from interruption of water supply at normal times. In many cities it is quite common practice during bad fires to increase temporarily the water pressure in the district adjacent to the fire. It is very obvious that a badly corroded water main might be capable of withstanding the normal pressure on the system and thus give no warning of the weakened condition of the pipe, but at the critical juncture during a bad fire when the pressure is suddenly increased the pipe may burst, and thus seriously hamper the work of fire fighting. It will readily be appreciated that in any region in which electrolysis damage is known to be in progress to a greater or less extent the mains are far more likely to break at these critical times than at any other period, and thus a real, though indirect, fire and life hazard due to electrolysis must be recognized.

Current Work on Electrolysis Mitigation and Related Problems.

In the field of electrolysis mitigation the work has been greatly curtailed during the year since practically all the men formerly engaged in it have been diverted to military problems. The work done has been largely accomplished by a single member of the staff.

Electrolysis Surveys.—Electrolysis surveys were supervised in St. Paul and Duluth during the summer of 1917. In December and January a similar investigation was made in New Orleans. The recommendations of the Bureau are being carried out in St. Paul and Duluth; but no action has been taken as yet in New Orleans. The Bureau has recommended a three-wire system for this city, which, if installed, will be the most complete and extensive system of its kind in this country.

The electrolysis conditions in a number of cities were investigated by conferences with the different companies concerned. In Los Angeles it was found that the three-wire system is being extended to three or four additional substations, and the engineers of the railway company reported complete satisfaction with this type of power distribution. Rather careful study was made of the cause of corrosion of gas mains, and surveys were made in Aberdeen and Hoquiam, Wash.

The Bureau has been asked to supervise electrolysis surveys in Milwaukee, and in Marion, Ohio, and it is expected that this work will be taken up immediately.

Results of Previous Work.—As a result of the Bureau's investigation of conditions in Springfield, Mass., the Springfield Railway Company is preparing to operate their cars on a three-wire system. It is believed that this installation will be completed during the summer of 1918. In the city of Omaha, after a trial of the three-wire

system in the Lake Street district, the main-station district was also converted for three-wire operation, and is now giving excellent results with regard to electrolysis. The Omaha electrolysis committee has just completed a survey, and the results show excellent conditions prevailing over the entire city. The recommendations of the Bureau have been carried out in practically every detail, and the work of the permanent committee has been very satisfactory. It is believed that, as a result of this work, no further important electrolysis trouble will occur in that city.

Revision of Paper on "Electrolysis and its Mitigation."—Technologic Paper No. 52, entitled "Electrolysis and Its Mitigation," has had a wide distribution. Since the original edition has been exhausted, a revision has been made, and a second edition is ready for printing. In this new edition the three-wire method of power distribution has been discussed at some length, and a new discussion of the subject of pipe drainage has been included.

Field tests on lead pipes have been begun to determine the extent of natural corrosion resulting from various kinds of earth encountered in city streets. Specimens have been buried on the Bureau grounds in the following different soils: Compost consisting of leaves and street sweepings, hydrated lime, cinders, Portland cement, fresh street sweepings, vegetable mold. This investigation was instituted as a result of numerous reports of corrosion of pipes and cables from causes other than electrolysis. It will require at least two or three years to secure definite results from these experiments.

Electrical Resistance of Street Railway Roadbeds.—For the past 3 years field work both on city streets and on the Bureau grounds has been under way to determine the electric resistance of different kinds of street railway roadbeds. Some tests are also being made in Madison, Wis., by the Forest Products Laboratory in collaboration with this Bureau. A technologic paper covering this work has been practically completed.

TELEPHONE-SERVICE STANDARDS.

(Systems of telephony; standards of telephone service. This section has also dealt with standard electric cells and has done much of the work on vacuum tubes.)

Telephone-Service Standards.

The investigation of telephone-service standards is of great importance, not only to public utility commissions, but to the telephone-using public at large. Nearly every branch of telephone engineering is involved. Standards of transmission, traffic conditions and the methods of handling traffic, the equipment used in the various systems, including subscribers' instruments, apparatus used in central office and private branch exchanges, and the wire plant necessary for subscribers' lines and trunks all have a very direct bearing on the quality and the cost of service rendered the public. The staff for handling the work has been increased during the year, and it is hoped that a more substantial increase will be possible in the near future so that the work may be more actively prosecuted.

Standards of Telephone Transmission.

Progress has been made in the measurement of the efficiency of telephone transmission, and in the development of standards upon

which this and much allied work must be based. Some of the work done for the military establishments has contributed indirectly to this development. A large number of comparisons of the efficiency of transmitters has been made. A study has been undertaken of problems which are involved in the highly complicated subject of telephone transmission, and a knowledge of which is essential to the interpretation of the results of transmission measurements. On account of the complexity of modern telephone circuits, this is a laborious undertaking, involving not only the development of suitable methods, and the making of measurements under the manifold conditions met in practice, but also the determination of the constants of representative types of telephone apparatus under service conditions. Such work is of great general value, and has also a direct application in question of telephone service with which public utility commissions have to deal, such for example as the feasibility of physical connection between different telephone systems.

Study of Local Telephone Service.

During the latter part of the year nearly the whole time of the Telephone Section has been devoted to a study of the local telephone situation in Washington, in connection with the rate case pending before the Public Utilities Commission of the District of Columbia. This is an unusually important case, involving the problem of deciding on proper measures to meet the unprecedentedly high operating expenses encountered by the local company under war conditions, and also the question of the introduction of automatic switching equipment to reduce the operating expenses, which the commission wished to have investigated. Throughout the case the engineers of the Bureau have acted as technical advisers to the commission. At the request of the Postmaster General a report of the whole matter was prepared and rendered to him. It contained a digest of the hearings held by the commission, analysis of the local telephone situation as brought out in those hearings, and a discussion of the relative advantages and limitations of the manual, semiautomatic, and the fully automatic systems of telephony, with particular reference to their possible use in meeting the emergency in this case. The report was submitted by the Postmaster General to the House of Representatives' Committee of the District of Columbia, and was published as a supplement to the House of Representatives' Report, second session. Arrangements have been made for the engineers of the Bureau to testify in further public hearings to be held by the commission.

Battleship Fire-Control Telephone Equipment.

An important test of battleship fire-control telephone equipment was made for the Bureau of Steam Engineering of the Navy Department. Equipment submitted by 2 makers was so assembled as to facilitate tests in accordance with suggested Navy Department specifications. One of the sets which was tested represented the equipment installed on the U. S. S. *South Carolina*. Equipment submitted by another maker represented two types of circuits and allied apparatus, one being that designed for installation on the U. S. S. *Florida* and the other that already installed on the U. S. S. *Utah*.

The observations made included tests for volume of transmission for intelligibility and for naturalness of the sound transmitted. Tests were also made for mechanical defects and to determine electrical properties of the transmitters.

The Navy Department having made a formal request that the Bureau of Standards assist in drafting new specifications for battleship fire-control telephone equipment, an inspection trip was made to one of the naval bases, where both types of equipment were thoroughly inspected under service conditions and additional syllabic tests were made. These confirmed our laboratory tests.

The matter of new specifications will be taken up as soon as opportunity offers.

Microphones.

A considerable portion of the last half of 1917 was devoted to experimental work in connection with sound detecting devices. Special microphones were designed and numerous experiments were made. Tests were made using various sources of sound and with and without the use of amplifiers.

Considerable experimental work was also done with various forms of microphones for the detection of subterranean sounds. These included the electrostatic and electromagnetic types as well as the usual microphone. Several types were produced which gave fairly satisfactory results. Some of this work is being carried on as time permits with the hope that an acceptable instrument may be produced.

In connection with the microphone work, studies have been made of the theory of the electrical and mechanical characteristics of various telephone transmitters, of diaphragms and membranes, and of vacuum tubes not only as amplifiers, but also as oscillators and detectors.

Standard Cell Work.

The investigation of the cause of the cracking of Clark cells and the best method of preventing it has been continued. Nearly two years ago 18 cells of this type were set up, blanks being employed in which the platinum terminals of the zinc limbs were subjected to the action of zinc amalgam before being sealed into the cell wall. Until this time none have cracked and they have remained remarkably constant.

3. HEAT AND THERMOMETRY.

[Establishment of the standard scales of temperature throughout the range of measurable temperatures; testing and standardization of thermometers, pyrometers, and other temperature-measuring instruments; determination of specific and latent heats, heats of reaction, melting and freezing points, and other properties of materials in the determination of which precise heat and temperature measurements are the principal requirement; standardization of calorimeters; production and distribution of standard heat and temperature samples; industrial applications of heat and temperature measurements; determination of fundamental engineering data involving thermal constants; determination of the fire-resistive properties of structural materials; investigations relating to airplane and other internal combustion engines and their auxiliaries.]

THERMOMETRY.

(Researches on standard temperature scales and thermometric fixed points; standardization of instruments and methods for measuring temperatures up to about 500° C.)

Clinical Thermometers.

During the year, the new clinical thermometer certificates described in the last annual report have been issued and appear to be

giving satisfaction. The new edition of Circular No. 5 on the Testing of Clinical Thermometers has been widely distributed during the year. Specifications for clinical thermometers were prepared for the use of and were adopted by the Medical Supply Depot, United States Army.

Some manufacturers of clinical thermometers had been issuing certificates which were misleading, as on any but the most careful inspection it would appear that such certificates had been issued by the Bureau of Standards. The Bureau informed the manufacturers of its desire to have the practice discontinued. The manufacturers, through their association, agreed to discontinue the use of certificates objectionable to the Bureau. It is believed that the use of misleading certificates will be practically eliminated.

Airplane Thermometers.

In July, 1917, an investigation of airplane thermometers was begun. Tests were made of instruments offered by American manufacturers and of such foreign instruments as were available. Investigations as to the nature of tests required and of methods of carrying out such tests were also made. In cooperation with the Signal Corps, specifications for several types of airplane thermometers were prepared. These were among the first specifications for airplane instruments to be issued by the Signal Corps, and served as a type for others. The Bureau was also of service in finding sources of material required in the manufacture of the thermometers. Several inspectors for the Signal Corps received instruction in testing methods in the thermometric laboratory. The Bureau has tested a certain proportion of all thermometers purchased and has made several minor investigations in connection with these tests.

Copper-Constantan Thermocouples.

The Bureau has a small stock of selected constantan wire from which a number of very homogeneous thermocouples have been constructed. A convenient flexible mounting has been designed and several couples have been calibrated at low and high temperatures. It has not, however, been possible to obtain wire of sufficient homogeneity to permit construction of precision couples without considerable care in selection and matching of wires.

Low-Temperature Scale.

A number of vapor pressure thermometers, consisting of a barometric column connected to a tube containing a condensible gas (oxygen, carbon dioxide) were prepared and used in the calibration of several platinum resistance thermometers. The temperature scale so established will serve as a working scale for testing and as a tentative basis for certain low-temperature researches of a military character.

Antifreezing Solutions.

In collaboration with the chemical division, a circular letter on antifreezing solutions for use in automobile radiators was prepared and issued. The freezing points of various glycerin-water, alcohol-water, and glycerin-alcohol-water solutions were determined in the laboratory. The freezing points of a number of proprietary antifreezing compounds containing principally calcium chloride were determined.

Solidifying Point of Naphthalene.

A standard method for determining the solidifying point of naphthalene was required by the Treasury Department for use in the Customs Service. On December 7, 1917, representatives of the various customs laboratories met at the Bureau for a conference which was also attended by several members of the Bureau's staff. A report of preliminary investigations by the Bureau was presented. A method for determining the solidifying point was agreed upon. The Bureau was requested to prepare the detailed specifications for the method and for the thermometers to be used. This has been done, and the thermometers were purchased and tested at the Bureau. It was also agreed that the Bureau should distribute a number of samples of naphthalene to the various laboratories for comparative tests. The samples have been distributed and results should be available shortly.

PYROMETRY.

(Researches relating to temperature scales, melting points, specific heats, latent heats, thermal conductivities, and other properties of materials at high temperatures; heat treatment of materials; investigation and testing of high-temperature measuring instruments; the application of pyrometric methods to industrial problems.)

Pyrometer Absorption Glasses.

A paper on the proper type of absorption glass for an optical pyrometer appeared in Journal of Washington Academy of Sciences. This paper described the specifications for absorption glasses applicable for precision work in extrapolating the high temperature scale. The specifications were adopted by the American manufacturer of optical pyrometers.

Optical and Radiation Pyrometry.

A general outline of the theoretical principles of optical and radiation pyrometry and methods of determining the fundamental constants of pyrometry were described in a paper published in the Transactions of the London Faraday Society.

Optical Ammeter.

A paper was published in the Journal of Washington Academy of Sciences describing a hot-wire alternating-current or direct-current ammeter in which the hot wire is operated at a visible heat. Measurements are capable of high precision.

Standardization of Thermocouples.

Methods suitable for calibration of base metal and rare metal thermocouples and precautions necessary in the measurement of temperatures by means of thermocouples were described in two papers appearing in Metallurgical and Chemical Engineering. This subject is of timely importance and the methods outlined have been followed by many technical industries engaged in the production and heat treatment of shell, guns, and various metallurgical products.

Wehnelt Tube Discharge.

In connection with the determination of certain physical constants, especially latent heat of vaporization, an investigation of the Wehnelt discharge tube was necessary. Two papers upon this subject appeared in Journal of Washington Academy of Sciences showing

that a film of high resistance forms at the surface of a probe wire placed in the anode glow of a Wehnelt discharge. It was found that a potentiometer or electrometer should be employed for measuring the anode fall, or if a voltmeter is used, correction must be made for the resistance of the film. The laws of shunt and series resistance hold for these polarization films.

Simple Method of Measuring EMF Accurately.

Two new methods applicable to determining temperatures with a thermocouple, measuring potential drop across resistance standards, were developed.

Pyrheliometers.

In Bureau of Standards Scientific Paper No. 323 are described methods of calibration and the behavior of the type of pyrheliometer used by the United States Weather Bureau for the measurement of solar radiation. Within the errors of observation, the solar radiation scale defined by this investigation agreed with the standard pyrheliometer scale of the Smithsonian Institution.

Standard Samples for Thermometric Fixed Points.

The standard scale of high temperatures is most conveniently reproduced by the use of certain pure metals, the melting or freezing points of which have been carefully determined. A large number of such standard melting point samples of very pure tin, zinc, aluminum, and copper were prepared during the previous year. One hundred and twenty-one of these samples were supplied to various metallurgical industries for use in standardizing the master thermocouples used to check the numerous pyrometers throughout the works. That these standard samples have proved of great service to the industries is attested by the fact that the demand for them from arsenals, navy yards, and other industries engaged on military work greatly exceeds the stock which this division has been able to prepare with the personnel and funds available for this work.

Investigations in Electronics.

A series of investigations have been completed on the determination of resonance and ionization potentials for electrons in vapors of boiling metals. When electrons are accelerated in a metallic vapor, two types of inelastic impact between an electron and an atom occur. The first of these results in an orbital shift of the electrons bound in the atom and the second in the complete removal of an electron or ionization of the atom. The potential differences through which an electron must fall to give sufficient velocity for these two types of collision are known as the resonance and ionization potentials for the particular metal in question. Work of this character, which is of great interest from the standpoint of theoretical physics, has also many important practical applications. Thus the data so far obtained have resulted in the determination of one of the important physical constants of optical pyrometry. The work has a direct bearing on problems in illumination by the electrical excitation of gases, on the possible nature of gaseous explosions, on methods of modifying and detecting electrical oscillations, etc. That the possible practical applications are many is evidenced by the fact that several of our largest industrial laboratories are undertaking work of this

character. Papers describing these researches have been published and others are in press.

Thermoelectric Power of Liquid-Solid Metals.

The determination of the thermoelectric power of liquid-solid metal thermocouples is of considerable interest from the standpoint of electronic theory, and of importance in adding to our knowledge of physical constants. The work with tin has been completed, and the investigation will be extended to other metals.

Airplane Gas-Engine Explosion.

This problem has arisen as a by-product of the work on ionization. In the further improved design of spark plug and sparking device for gas engines it is essential to understand the physical mechanism of an explosion. The first step under way in the problem is the determination of whether or not an explosion can be produced by ionization due to photoelectrons liberated by excitation of a metal with Röntgen rays.

Annealing of Optical Glass.

The manufacture of optical glass must be followed by a thorough heat-treating process in order to remove the mechanical strains in the glass. This new problem has arisen with the necessary and rapid development in the American manufacture of optical glasses required in the production of military instruments. For each type of glass it is necessary to determine the temperature at which the glass becomes sufficiently mobile to allow the internal stress to dissipate in a reasonable time. The annealing temperatures of the optical glasses made by the Bureau have been determined by different methods, and investigation is being conducted to establish the relationship existing between the various physical properties of the glasses and the process of annealing. These properties include viscosity, thermal expansion, electrical conductivity, thermal characteristics and transformation points, birefringence, etc. Briefly stated, the object of the present investigation is (1) to determine the temperature at which the strain existing in a sample of glass of specified dimensions is dissipated in a specified length of time, usually 10 hours; (2) to determine the maximum rate at which the glass can be cooled without danger of introducing permanent strain, and (3) to determine the maximum temperature at which the annealed glass can be removed from the furnace without danger of fracture. The above characteristics depend upon the size and kind of glass, but fortunately these may be in general reduced to standard practice, thus greatly diminishing the number of variables affecting the process of annealing. The work has been developed to such an extent that routine tests are being conducted for various American manufacturers, and a complete report will be published later this year.

Temperature Problems in Coke Ovens.

The investigation of the coke ovens ordered by the President in order to determine the relative merits of these two ovens for coking certain grades of coal for use in the iron industry of Illinois and vicinity was made by representatives of the high-temperature laboratories in connection with the study of the temperature conditions under which these ovens are operated. Measurements were made of

temperatures of the coal during coking, of the heating walls, of the ovens while empty, in the regenerators, in the waste-heat flues, in the hot-vapor mains, etc. A considerable amount of valuable information has been accumulated. The work will be extended and a complete report submitted later.

HEAT MEASUREMENTS.

(Thermal constants and thermal properties of materials at low and ordinary temperatures; heats of reaction; investigation and tests of methods and instruments.)

Standard Heat Samples for Use in Calorimetry.

Large fuel contracts are now quite generally based on heating-value tests made with calorimeters. The Bureau has furnished during the year 153 standard heat samples of sugar and naphthalene, which have served the important purpose of enabling users of calorimeters to conveniently check the accuracy of their fuel tests.

Refrigeration Constants.

This extensive series of investigations, undertaken at the request of American refrigeration engineers, expressed through their national associations, includes the determination of the fundamental constants of refrigeration engineering. The work is being carried out with the cooperation of committees of the American Association of Refrigeration and the American Society of Refrigerating Engineers, the members of which have kept in close touch with the work by visits to the Bureau and by means of the reports presented before the annual meetings of these societies by members of the Bureau's staff. The complete series of investigations contemplated under this topic was outlined in the annual report for 1916. Most of the staff engaged on these investigations have been diverted to another investigation of somewhat similar character but of immediate military importance. The work done during the year is briefly summarized in the following sections.

Thermal Constants of Ammonia.

The specific heat of anhydrous ammonia in its liquid and vapor phases and its latent heat are among the most important constants of refrigeration engineering. The experimental work involved in the determination of these constants was completed during the previous year, and a brief statement of the methods employed and the results found was given in the annual report for 1916–17. During the early months of the present year the results of these investigations were finally worked up and have since been published as follows: Bureau of Standards Scientific Paper No. 301, An Aneroid Calorimenter for Specific and Latent Heats; Bureau of Standards Scientific Paper No. 313, Specific Heat of Liquid Ammonia; Bureau of Standards Scientific Paper No. 314, The Latent Heat of Pressure Variation of Liquid Ammonia; Bureau of Standards Scientific Paper No. 315, Latent Heat of Vaporization of Ammonia. Projected work on the specific heat of superheated ammonia vapor was deferred for the future.

Specific Volumes of Ammonia and Ethyl Chloride in the Liquid and Vapor Phases.

The experimental work incident to the determination of the specific volumes of these refrigerants in the interval —50° to +50° C.

has been nearly completed. One method used was an application of the well known mass-volume method. An optical interformeter method has also been applied to the determination of the specific volume of the vapor phase, making use of the relation between refractive index and specific volume. When opportunity affords, the large amount of experimental data that has been obtained will be worked up and put into form for publication.

Special Military Investigations.

Several special military researches have been under way in this division during the latter part of the year and have occupied the greater part of the time of a number of the senior men of the division.

LOW TEMPERATURE.

(Production of low temperature down to those of liquid hydrogen (ultimately liquid helium); preparation and storage of pure gases; development of methods of producing and maintaining low temperatures; liquefaction and separation of gases at low temperature; special tests requiring the facilities of the low-temperature plant.)

Low-Temperature Laboratory.

This laboratory has continued to furnish during the year to the several laboratories of the Bureau, as well as to other Government laboratories, special facilities for tests and investigations requiring low temperatures and gases at high pressures. Liquid air runs were made on 36 occasions, the total aggregating some hundreds of liters. Seven compressed air runs were made for the low-temperature comparators in the thermal expansion laboratory. The air compressor was frequently operated for work on noxious gases, for development work on air inductors, tests of silencers, oxygen valves, high-pressure metal hose, etc. Electrolytic oxygen was furnished continuously in large amounts to the chemical laboratories, and for welding purposes. Air and hydrogen, highly compressed in cylinders, were furnished to the various laboratories of the Bureau and to the Signal Corps for special investigations.

The carbon-dioxide cycle was operated almost continuously to provide cooling for the refrigeration constants work; for the thermometer comparators of the heat division, and for development work, by the Aeronautical Instruments Section, in connection with aviators' oxygen regulators. It was also used for tests by other divisions of the Bureau and for low-temperature tests of aeroplane watches, lens systems, electric batteries, rubber samples, and aviators' masks.

The acetylene generator was kept in operation to supply acetylene gas as needed.

A new air liquefier involving a rather unique automatic float valve for discharging the liquid air without waste of cold air was built and installed. While this addition increased the output of the plant to the full capacity of the compressor, it was built chiefly for the sake of providing duplicate equipment as insurance against accident. The liquefier which had previously been depended upon for the supply of liquid air was overhauled and provided with the automatic outlet.

The separate parts of an improved hydrogen liquefier were tested and assembled. This will be put into operation in the near future.

A liquid air and charcoal purifier for hydrogen was built for use on the liquid hydrogen cycle.

Two rotary vacuum pumps were installed for use in series with mercury condensation pumps to give vacua of the order of 0.00001 millimeter of mercury. This assembly of pumps for high vacuum work, while primarily designed for study of rare gases, has proved very useful for the exhaustion of Dewar flasks, mercury arc lamps, special manometers, barometers, and electrical devices.

Preparations have been made to install early in the coming year a new hydrogen compressor and two 90-foot gas holders, deliveries of which are expected within a few weeks. The latter are of the annular type and arranged for variable water loading.

A second electrolytic oxyhydrogen gas generator was installed, thus balancing the load across the three-wire electric circuit.

A gasoline bath, suitable for cooling large specimens to as low as −50° C. by means of the carbon-dioxide cycle, was constructed and has been used frequently for special military tests.

This laboratory has also cooperated in the calibration of a set of orifice air meters for the War Department; the production of liquid oxygen for standard temperature bath; tests of special pressure gauges, and tests of airplane unit sights for fogging with moisture under conditions occurring in aviation.

The Bureau was enabled, with the facilities afforded by the low-temperature laboratory, to prepare a quantity of pure neon from a mixture of helium and neon submitted by an industrial research laboratory. The mixture, from which half a liter of neon was separated, was the volatile inert residue derived from atmospheric air. The neon was condensed in coconut charcoal surrounded by liquid hydrogen and later removed at liquid air temperatures. Members of the optics division kindly assisted in the spectroscopic control.

There is still needed for the completion of the liquid hydrogen plant a compound rotary vacuum pump of considerable capacity for evaporating the precooling air under reduced pressure. This equipment should be provided as soon as possible.

The next stage in the development of the low-temperature laboratory will include provision for the production of liquid helium, thus extending the facilities of the laboratory to the lowest attainable temperatures. It is hoped that funds may be available to provide this equipment in the near future.

FIRE-RESISTIVE PROPERTIES OF STRUCTURAL MATERIALS.

(Standardization of fire tests; fire tests of structural materials and structures; investigation to develop engineering data relative to the fire-resistive features of building construction; investigation and testing of fire-retarding devices; investigation of building codes and fire codes; cooperative work on fire prevention.)

Fire-Resisting Properties of Structural Materials.

The object of the investigations on the fire-resisting properties of structural materials is to furnish architects, construction engineers, builders, State and city building bureaus, insurance interests, and others with fundamental engineering data relating to the behavior and safety of various types of building material and construction when exposed to different conditions met with in fires.

Fire Tests of Building Columns.

Many millions of dollars are spent annually on the construction of buildings, the integrity of which, in the event of fire, is dependent on the behavior of the steel columns supporting the structures. Very little engineering data are available which would permit of any certain conclusions as to the thickness and kind of fireproof covering required to render these columns safe under various conditions of fire hazard. The requirements of city building codes on these questions are so different that it is evident that either some codes are requiring unnecessarily thick fireproof coverings, with undue increase in construction costs, or else other codes are requiring too thin coverings, with undue increase in danger to the stability of the structure under the existing fire hazards.

The fire tests on building columns are being conducted jointly by The National Board of Fire Underwriters, the Associated Factory Mutual Fire Insurance Companies, and the Bureau of Standards. The present program of tests was formulated after consultation with many engineers and architects interested in fire-resisting building construction.

Types of columns.—The types of columns being tested include rolled steel sections, built-up steel sections, round cast-iron sections, steel pipe filled with concrete, vertically reinforced and hooped concrete columns, and wooden columns. At least one of each of the sections is unprotected, others are partially protected by filling the reentrant portions with concrete, and others are completely protected by various thicknesses of concrete, clay tile, filled and unfilled gypsum blocks, plaster on metal lath, and common brick, in accordance with the methods commonly employed in practice.

Materials.—The materials used in the construction of the test columns and protective coatings have been obtained from various sections of the country, and have been selected with a view to obtaining those representative of their respective classes.

The column coverings have been applied by experienced men in accordance with plans and specifications drawn to secure average results obtainable under ordinary commercial conditions.

Methods of test.—In the fire tests the column, mounted within a gas-fired furnace and kept under normal working load applied by a hydraulic ram of special construction, is exposed to a predetermined furnace temperature rise until the column fails. A record of the temperature at different points within the furnace and at various points within the test sample is obtained by means of suitable thermocouples. The deformation of the column from time to time is determined by means of pairs of nichrome wires inserted into the column at a known distance apart and extending horizontally outward through the walls of the furnace, the wires being run coaxially through fire-clay protecting tubes.

In the fire and water tests, the column is exposed to a furnace temperature built up at the same rate—i. e., in accordance with the standard time-temperature curve that has been adopted for these tests—until the desired temperature rise in the furnace is attained, when two opposite walls of the furnace are rolled out of position by means of trolleys provided for this purpose and the hose stream applied.

Tests completed.—A total of 75 columns have been tested during the year. These comprise 10 tests of unprotected steel and cast iron columns, 11 tests where the metal was partly protected by filling the reentrant portions or interior with concrete, 24 were protected by 2-inch and 4-inch concrete coverings, 17 by 2-inch and 4-inch hollow clay tile, 2 by common brick, 5 by single and double layer of Portland cement plaster on metal lath, and 6 were vertically and laterally reinforced concrete columns. The coverings and columns were designed according to standard methods of current practice applied in a manner best adapted to secure quality of workmanship obtaining on ordinary construction work. Under the conditions of the tests the columns so far tested stood up for periods varying from 11 to 35 minutes, for the unprotected steel and cast iron columns, to over eight hours for the heavier types of full protection, which demonstrates the danger incident with the use of unprotected columns even under conditions of moderate fire hazard and also the practicability of obtaining adequate protection with the use of moderate amounts of covering materials properly selected and applied. The effectiveness of the protection was found to vary greatly within any given class of protecting materials depending for example upon the aggregate used in the concrete, the type of clay in hollow tile, etc., while duplicate tests with a given material showed only relatively small differences in the protection afforded.

Several hundred tests to determine physical, chemical, and thermal properties of the materials used have been made by this Bureau, as also calibrations of the loading ram of the column furnace and accessory testing machine.

A relatively small number of tests are required to complete the program, after which the results will be prepared for publication.

A brief prospectus of the proposed tests was issued early in the year.

Fire Tests of Reinforced Concrete Columns.

Fire tests of reinforced concrete columns now being carried out at the Pittsburgh laboratory are intended to supplement the column tests being made at Chicago, as the latter relate mainly to structural steel columns. The equipment installed for these tests was briefly described in the last annual report.

Types of columns.—Fifty-four columns have been cast. The columns include square sections 16 by 16 inches with 2 per cent vertical reinforcement, and circular sections 18 inches in diameter, some with 2 per cent vertical reinforcement, others with 2 per cent vertical and 1 per cent of spiral reinforcement, and a few without reinforcement. In all cases the covering outside of the reinforcement was 1½ inches of concrete. All columns were 8 feet 9 inches long. Two types of aggregate, washed river gravel and a high calcium limestone, both from the Pittsburgh district, were used. Preliminary tests of 4 aggregates showed the ones selected gave concrete of very poor and very good fire-resisting properties, respectively.

Methods of test.—Three columns of each type were made. One of these was tested to failure when cold. In the fire tests the column, mounted within a gas-fired furnace and kept under normal working load applied by a hydraulic ram, is exposed to a predetermined furnace temperature rise until the column fails, or until the end of 4

hours. If failure does not occur in the 4-hour period, the load is increased to 600,000 pounds, the limit of the testing equipment; if this does not cause failure, the column is allowed to cool and is subsequently tested to failure in a large testing machine. During the fire test a record of the temperature at various points within the furnace and within the column is obtained by means of suitable thermocouples.

Tests completed.—Forty of the columns have been tested. The most notable result of these tests is the earlier failure of the gravel concrete columns, due principally to the spalling off of the outer perfecting layer of concrete, thus exposing the steel and load bearing concrete to the fire. For example, a square limestone-concrete column, with 2 per cent vertical reinforcement, had lost about 55 per cent of its strength at the end of the fire test, while a similar gravel concrete column had lost about 80 per cent of its strength.

Of the cylindrical columns with 2 per cent vertical reinforcement, the limestone concrete columns showed about the same loss of strength in the fire test as the corresponding square columns, while the gravel concrete columns showed less loss of strength than did the corresponding square columns.

Of the cylindrical columns with 2 per cent vertical and 1 per cent spiral reinforcement, the limestone concrete columns showed the smallest loss of strength and the gravel concrete columns the greatest loss of strength of any of the columns tested.

Supplementary tests.—In order to determine the effectiveness of an additional outer layer of fireproofing material to prevent spalling of the concrete, additional tests were made of gravel concrete columns. One of the square gravel-concrete columns, which was protected with one inch of gypsum plaster with very light expanded metal reinforcement, lost only about 40 per cent of its strength in the fire test. The cylindrical vertically and spirally reinforced gravel concrete columns, with a similar additional protection, withstood the 600,000 pounds load at the end of the fire test, and one column tested subsequently when cold had lost only about 10 per cent of its strength.

It is clearly indicated that aggregates high in quartz introduce a serious hazard in fire-resistive concrete, but that this hazard can be practically eliminated by the use of suitable protective material.

These experiments have a bearing on the use of protective coatings to take care of the fire hazard, together with a possible reduction in the high factors of safety at present considered necessary in concrete construction. The experiments with protective plasters of various types will be continued.

A more detailed progress report describing the fire test on reinforced concrete columns has been published in the Proceedings of the American Concrete Institute.

Strength of Metals at High Temperatures.

An apparatus for determining the compressive strength and elastic properties of materials as affected by heat has been completed during the year. This has a maximum load capacity of 100,000 kilograms and will take specimens up to 12½ centimeters diameter and 25 centimeters long and subject them to temperatures up to 800° C. The load is applied by hydraulic pressure within a horizontal restraining frame of structural steel, the heat being supplied by a circular elec-

tric furnace with concentric end coils to compensate for conduction losses. The deformation is measured over a 15-centimeter gauge length using microscope settings on wires attached to the specimen and extending to the outside of the furnace. A series of 60 tests on specimens of structural steel, cast iron, and concrete is under way which it is expected will give much needed information on the properties of these materials at high temperatures.

Building Codes, Information, Cooperative Work.

Considerable correspondence has been carried on with engineers, State fire marshals, and others interested in fire-protection work, and the bureau has cooperated with committees on the standardization of fire tests and on safety to life.

Cooperative work has been done by participation in committee work and in the preparation of reports for the Office of the Quartermaster General on the following subjects: Handling of petroleum and coal-tar products, spontaneous combustion of cotton in bales, the fire hazards in connection with wet and dry processes of cleaning and sterilizing Army uniforms, plaster wall boards, paper safety matches.

Some work has been done in collecting, for the Tariff Commission, information regarding the hazards of the various kinds of imported safety matches.

Further work has been done on an index for collating information relating to fire-resisting features of building construction.

Comparisons have been made of 15 city building codes in reference to the following features of building construction: Height of buildings; wall thickness; fireproofing of building columns, etc.

The section on "The fire hazard in the home" for the Bureau of Standards Circular 75, on Safety for the Household, was completed and the circular published.

AIRPLANE POWER PLANT.

(Investigations and tests relating to airplane engines, fuels, carburetion, cooling systems, ignition systems, and other auxiliaries, with special reference to conditions of temperature and pressure obtaining in actual use; special problems in lubrication.)

Altitude Laboratory.

There has been constructed an altitude laboratory, in which aeronautic engines can be tested under all conditions of temperature and pressure met with in flight. This apparatus is housed in a temporary building of 24 by 50 feet floor area. This laboratory was completed in January, and investigations have been under way continuously since that time. A total of about 120 sets of observations have been made covering 500 or 600 hours actual engine operation.

Results of utmost importance have been secured on various features of engine performance at different altitudes. Confidential reports of about 12 in number are in the course of preparation covering part of the results obtained in these results.

Additional Equipment.

A second 24 by 50 foot building has been constructed in which is housed a 400-horsepower dynamometer with necessary testing equipment and a torque stand on which engines can be run with propeller load. These two units have been in use since their completion for spark-plug and lubrication tests and other special tests described below.

Spark Plugs.

An investigation of the design and characteristics of spark plugs and ignition appliances was undertaken in 1917 and has been continued throughout the year. Methods of testing spark-plugs have been developed and, on recommendation of this Bureau, adopted by the Bureau of Aircraft Production. A systematic study has been made of the electrical and mechanical characteristics of some 50 different porcelain compositions for the purpose of selecting the best material for spark-plug insulators. This investigation has led to the adoption of a porcelain having a marked superiority to any porcelain previously used for the purpose.

The Bureau has taken charge of the routine testing of spark-plugs for the Signal Corps and the Bureau of Aircraft Production, for which purpose aeronautic engines have been in operation a considerable part of the time on the dynamometer laboratory torque stand.

A study of the characteristics of a number of different types of magnetos has been completed and has yielded results of value. The results of the ignition investigation are included in some 15 confidential reports, some of which have been compiled and distributed.

Carburetion.

A study of the problems of carburetion for aeronautic engines has been under way partly in connection with the tests in the altitude laboratory. Results of utmost importance have been obtained indicating serious faults with all existing carbureting systems at high altitudes and furnishing data from which it is hoped radical improvements may be developed.

Radiators.

A fundamental study of the problem of radiator construction for high-speed airplanes undertaken in 1917 has been continued throughout the year. Careful analyses have been made of the performance of something over 100 radiator designs under various conditions of air speed and air temperature. The results of this investigation are being compiled into a series of confidential reports now nearly completed. The work done so far represents substantially a completion of the program as adopted a year ago. There remain several important features of this problem to be undertaken. Additional information is needed on the performance of radiators in flight; on the characteristics which are desirable for radiators placed in various positions on fusilage; on the effect of radiator design and location on head resistance of the plane; and on the effect of surface and length of radiator cells.

Lubricants.

Investigations of the behavior of a number of typical airplane engine oils have been carried out and engines running on the test stand. Analyses have been made of the used oils from engines which have been running in the altitude chamber from which valuable information has been secured. Recently a more fundamental laboratory investigation of the characteristics of different oils has been undertaken and has already yielded results of considerable interest.

Special Tests.

Special tests have been made on the performance of two new models of the Hispana Suiza engine in the altitude chamber with

special reference to proper carburation; of Liberty engines on the dynamometer stand and torque stand, with special reference to characteristics of performance, durability, and lubrication. In addition to this, tests of several experimental engines have been undertaken, in particular, one engine, designed under the direction of the National Advisory Committee for Aeronautics, was subjected to an extended series of tests. A brief series of investigations was undertaken with an experimental 1-cylinder Liberty engine. This engine has recently been mounted on a special test stand for the purpose of studying temperature and pressure distribution in the cylinder and in the various moving parts with a view to solving some difficult questions as to ignition and lubrication.

Activities in Conferences, Committees, and Scientific Societies.

Members of the Bureau have participated in numerous conferences with representatives of the military and other departments of the Government and with technical men visiting the laboratories. The committee work has frequently involved long and continuous service on committees considering important new military developments.

Ten papers bearing upon pyrometry and related subjects were presented before various scientific societies, such as Washington Philosophical Society, American Physical Society, and Optical Society of America. Abstracts of these papers have appeared in Journal of Washington Academy of Sciences, Physical Review, and Proceedings of National Academy of Sciences.

Heat and Thermometer Tests.

The tests completed in the heat division during the year are summarized briefly, as follows:

The number of mercurial thermometers of various kinds, exclusive of clinical thermometers, submitted for test, was 4,951, of which 4,464 received certificates or reports. Among those submitted were 341 Parr calorimeter thermometers, 19 high-precision calorimeteric thermometers, 146 Beckmann thermometers, 56 clinical standards, 2,330 industrial thermometers for the United States Shipping Board, Emergency Fleet Corporation, and the remainder laboratory and special thermometers of various types ranging from below 0° to 500° C. Two hundred and forty-eight indicating airplane thermometers of the vapor pressure and liquid expansion types were tested for the United States Signal Corps, the Navy Department, and various manufacturers. Of the 15,039 clinical thermometers submitted, 13,151 received certificates or reports giving results of test. In addition to the above there were tested 9 platinum resistance thermometers, 4 thermocouples, and freezing point determinations were made on 25 samples of materials (naphthalene, toluene, and fixe-extinguisher liquids).

In the high temperature laboratories the following tests were made: One hundred and fifty-four thermocouples; 13 indicating instruments for thermocouples; 23 homogeneity tests of thermocouples; 18 optical pyrometers; 5 absorption glasses; emissivities of 3 metals; heat resisting properties of 22 materials; heat treatment of 54 materials; melting point of 52 refractories; and 19 special tests. One hundred and twenty-one samples of metals with certified melting points were furnished to the technical industries. Among the special tests made in these laboratories the following may be mentioned:

Preparation of 400 standard melting point samples; life test of thermocouples; melting point of pyrometer porcelains; annealing of 5 samples of optical glass, 3 of which were 8-inch cubes for periscope heads; annealing temperature of 15 samples of optical glass; maximum safe temperature for removing various optical glasses from annealing furnace; specific heat of 2 samples of fire brick and 1 sample of gun metal; test of several thermocouples installed at the Washington Navy Yard; melting points of 2 aluminum soldering fluxes; temperature of 3 illuminating bombs for the Signal Corps; cooperation with the American University Station, Bureau of Mines, in the manufacture of arsene and other poisonous gases (50 furnace heats made); temperature measurements in Roberts' and Koppers' coke ovens.

The tests made in the heat measurements laboratories were: Standardization of 1 gas calorimeter; heat of combustion of 1 sample of fuel oil and of a number of samples of airplane engine fuels; the thermal conductivities of 32 samples of insulating materials; the thermal leakage of 7 food containers. One hundred and fifty-three standard combustion samples were furnished for the standardization of calorimeters.

The tests made in the low-temperature laboratory, either by its staff or in cooperation with others using the facilities of this laboratory, have been referred to under the section of this report relating to the low-temperature laboratory.

The total work of testing accomplished during the year greatly exceeds that of any previous year, and its increase is very considerably greater than the increase in the personnel engaged in this work. At least 75 per cent of the total testing was done directly for the various military and civil bureaus of the Government, and most of the remainder for industrial establishments engaged on Government work.

Information Furnished.

Several hundred letters and reports relating to the work of the heat division were prepared in reply to requests for information on testing of temperature measuring instruments, methods of temperature measurements, calorimetry, thermal conductivity, thermal constants, etc. Many engineers and technical men have visited the laboratories for consultation on special problems. A considerable number of devices were submitted for examination and criticism.

4. LIGHT, OPTICAL INSTRUMENTS, AND SOUND.

[Development of photographic plates sensitive to red and infra-red light; use of these color-sensitive plates in spectral investigation and for landscape photography; standards and testing of sugar and other materials by optical means; investigation of magnetite and optical properties of magnetic substances; color measurements and specification of color standards; artificial daylight; spectral transmission of dyes and other materials; interferometry; design of optical instruments; testing of optical systems; production and testing of optical glass; radiometry; transmissive and reflective properties of various substances; dispersoids; investigations in sound.]

SPECTROSCOPY.

(Measurement of standard wave lengths of light; application of such standards to the measurement of wave lengths of the spectra in chemical elements; development of data for the spectroscopic analysis of chemical compounds, alloys, minerals, etc.; development of photographic methods for investigating the red and infra-red spectral regions.)

Red and Infra-Red Spectra of Chemical Elements.

Researches in the red and infra-red spectra of chemical elements were continued during the past year with the aid of specially sensi-

tized photographic plates. Ordinary plates stained with photographic dyes such as pinacyanol and dicyanin were used for this purpose and a large amount of spectroscopic data has resulted.

The arc spectra of iron, cobalt, nickel, chromium, manganese, silicon, gold, silver, zinc, lead, aluminum, tungsten, and molybdenum were photographed in the region of long wave lengths. In order to determine to what extent photographic methods with a large diffraction grating are applicable to the infra-red spectral regions, the spectra of iron, cobalt, and nickel were photographed to the extreme limit which it is practicable to reach with our apparatus and photographic method. A large concave grating was used, and exposures up to 10 hours' duration registered many lines with wave lengths greater than 10,000A, or 1 micron. In the arc spectrum of iron, 298 lines were measured between the wave-length limits 6,750A and 10,689A; 606 lines were measured between 5,503A and 11,623A in the arc spectrum of cobalt; and 290 lines between 5,504A and 10,843A in the arc spectrum of nickel. These results (Scientific Paper No. 324) demonstrated that an invisible long-wave interval as large as the entire visible spectrum is accessible to photography with dicyanin stained plates. The incompleteness of spectroscopic data for these longer light waves invites extensive application of this method of spectrum photography.

A scientific paper entitled "Measurements of Wave Lengths in the Spectrum of Neon" has been completed and presented for publication. This paper contains the wave lengths of 55 strong lines in the red and violet portions of the neon spectrum. Interferometers were used to measure the wave lengths in terms of that of the red radiation from cadmium, which is the fundamental standard. The probable error of these wave lengths is about one part in seven millions, and these values will therefore be of importance as spectroscopic standards. Differences of vibration frequencies corresponding to these wave lengths are found to be exactly constant within the limits set by the accuracy of the wave lengths.

In addition to the strong lines mentioned above, the wave lengths of 189 less intense lines in the red and infra-red spectrum of neon were determined with the aid of a large concave grating and are included in this publication.

Other spectroscopic researches described in the last annual report were published during the past year as Scientific Paper No. 312, "Wave-Length Measurements in Spectra from 5600A to 9600A," and Scientific Paper No. 318, "Application of Dicyanin to the Photography of Stellar Spectra."

Red and Infra-Red Spectrum of the Sun.

A map of the solar spectrum from 6800A to 9600A was made from spectrograms obtained at the Johns Hopkins University last year, and this map was reproduced in the January number of the Astrophysical Journal. Measurements of the original photographs reveal nearly 2,000 Fraunhofer lines in this part of the solar spectrum. Thus far about 400 of these solar wave lengths have been identified with those of emission lines in the red and infra-red spectra of 19 of the chemical elements which have been studied in our laboratories.

Through the courtesy of Director Frank Schlesinger, the Porter spectrograph at Allegheny Observatory was used during the past

year for the continuation of work on the solar spectrum and data were collected to permit the absorption lines in the solar spectrum to be classified as solar or terrestrial. This spectrograph was designed for work on the rotation of the sun and served to separate the solar from the telluric lines by means of the displacement suffered by solar lines in consequence of the solar rotation. Excellent spectrograms were obtained between 5600A and 9400A, but instrumental difficulties made it impossible to photograph the spectrum beyond 9400A in sharp focus. Between these limits over 3,000 absorption lines were recorded. of which number about two-thirds were shown to be due to absorption of oxygen and water vapor in the earth's atmosphere. More extensive application of stained-plate photography to astronomical subjects promises to yield further important results in astrophysics.

Refractive Index and Dispersion of Air.

In connection with spectroscopic work it is necessary to know some of the optical properties of air. For example, the difference in the index of refraction of the air for different wave lengths must be taken into account in the measurement of standards of wave lengths, and for the proper discussion of numerical relations among spectral lines it is necessary to reduce wave lengths which have been measured in air to their value in a vacuum. This requires a knowledge of the index of refraction of air of various densities for a large range of wave lengths. Over 1,200 observations on the index of refraction of air of various densities were made for wave lengths from 2200A to 9000A, which is the entire spectrum range easily recorded by direct photography. Tables were prepared to enable the proper corrections to be made to standard wave lengths measured in air whose density is not normal and also make possible the conversion of wave lengths or frequencies measured in air to their values in a vacuum. The computations were completed during the past year and the results prepared for publication in Scientific Paper No. 327.

Landscape Photography With Red-Sensitive Plates.

The success in spectrum photography with plates sensitized to red and infra-red light with photographic dyes has led to their application to landscape photography. Their greatest importance arises from the fact that ordinary plates are sensitive only to shorter waves in the blue portion of the spectrum and these waves are largely scattered in the atmosphere. The intensity of this scattered light in the sky varies inversely as the fourth power of the wave length, so that red light of twice the wave length of blue would be scattered only one-sixteenth as much. The great value of red-sensitive photographic plates in penetrating the haze due to light scattered in the atmosphere has been fully demonstrated. Another important characteristic of these red-sensitive plates is their power to detect camouflage designed to defeat the eye. It has also been shown that in certain cases where contrast is especially important it is brought out much better by making use of red-sensitive plates.

Comparisons of numerous types of American and European commercial color-sensitive plates have been made. These plates have been compared among themselves and with plates sensitized by staining with dyes in our laboratories. This investigation has shown

that when certain dyes are applied to the proper photographic emulsions, the plates are superior to any others which have been available for this comparison, and these include the most recent commercial orthochromatic and panchromatic plates.

Appreciation of the importance of photographic dyes has created an interest in their production in this country. Heretofore the best photographic sensitizers were manufactured only in foreign countries, but now a number of chemists in this country are engaged in the problem and have already succeeded in making some of the most important dyes. The sensitizing power of a number of domestic dyes has been tested at this bureau, and the outlook for American photographic dyes is very hopeful.

In connection with these color-sensitive photographic plates the question of color filters has received considerable attention. Screens showing the greatest possible transmission of light in certain spectral regions are required and the production of such filters for use in special photographic work is of great importance. In the same connection some work has been done in designing photographic lenses which are corrected for the longer waves.

Spectroscopic Analysis.

Considerable time has been given to analyses by the spectroscopic method. The spectroscopic method is extremely sensitive and often detects impurities which escape the chemical method. In some cases the quantity of a sample is too small for a successful analysis by chemical means. The presence of all the constituents of a compound in a single small sample can generally be tested quite easily by a spectrum examination, while the chemical method often requires several portions of the material, each one of which is separately examined for a certain element or group of elements. Coordination of the results of spectroscopic and chemical analyses of standard samples in certain cases makes possible the substitution of a rapid and accurate spectroscopic method of quantitative analysis for a cumbersome chemical method. In cases where the chemical quantitative analysis can not be replaced by the spectroscopic method a rapid preliminary qualitative analysis by the spectrum often saves the chemist much time.

During the past year spectroscopic tests were made on a large variety of materials of which the following may be cited as typical.

The constituents of samples of optical glass and of colored glasses were found spectroscopically, and some of the materials used in the manufacture of optical glass were examined for impurities which might color the glass.

At the request of the zinc-refining industry, a considerable number of ores, electrolytes, anodes, etc., were examined to detect impurities which gave trouble in electrochemical processes.

A variety of cored and impregnated carbons used in electric arc searchlights were analyzed.

The spectra of various poisonous gases were examined, but it was found that their instability under the conditions required to produce a spectrum makes it difficult to detect them spectroscopically.

Various alloys such as "hardened" copper, "tempered" aluminum, nickel-tungsten and alloy steels were analyzed qualitatively from their spectra.

Several hundred samples of tin from steam boiler safety plugs were analyzed quantitatively for copper, lead, zinc, and iron by means of spark spectra. This is a case in which routine and wearisome chemical analysis can be replaced by easy and accurate spectroscopic work. Cooperation of spectroscopists and analytical chemists will make spectrum analysis more powerful and practicable in quantitative work.

POLARIMETRY.

(Standardization of materials, including sugars, sirups, and other compounds, by polarimetric methods; precision polarimetry, including the determination of polarimetric constants; development of standard definitions, methods, and instruments; calibration of polarimetric apparatus; standardization of the technology of sugars and related materials; research in all factors affecting the efficient organization of sugar manufacture and testing; sugar standards for precision calibration purposes; laws and principles of magneto optics and their practical application.)

Circular on Polarimetry.

Since the completion of Circular 44, on Polarimetry, referred to in the last annual report, it has been necessary to print two editions, and the third is now under way. The last edition of 1,500 copies was exhausted in three weeks, nearly the entire edition being purchased by the public. The demand has proved to be a confirmation of the Bureau's recognition of the possibilities of polarimetry in both science and industry.

Testing of Quartz Control Plates.

Quartz control plates are indispensable for the accurate daily checking of saccharimeters. Eight of these plates were tested and certified. Two of them, which were improperly mounted in wax, were removed from their original mounts and placed in loose metal holders in such a way as to comply with the Bureau's specifications.

Owing to the fact that all quartz control plates are imported from Europe it has been impossible to secure any for some time. With the object of being of the greatest possible assistance to the sugar industry in this emergency, the Bureau has abandoned its previous practice and whenever feasible is remounting and testing discarded plates in a manner to make them serviceable.

Natural Rotation of Quartz at High Temperatures.

The investigation of the natural and magnetic rotation of light by crystalline quartz at high temperatures has been continued. Additional knowledge of the properties of quartz is of special importance from the theoretical standpoint because of its extensive use in polariscopes and other optical instruments and because of its relation to the problems involved in the study of the history and formation of the earth.

Crystalline quartz has a transition point at about 574° C. At this temperature the crystal changes over into another crystal form with an absorption of heat when passing through the inversion point from a lower to a higher temperature, and an evolution of heat when going down through the point.

At this so-called "inversion point" it has been found that there is an abrupt jump in the natural rotation, its magnitude depending upon the wave length or color of the light used. Also, there is an abrupt change in the direction of the rotation curve below the point, a small temperature change causing a very large change in the rotation, while above even a large change in temperature has very little

effect on the rotation. The curve showing the rotation plotted against temperature was found to be a straight line almost parallel to the temperature axis from the inversion point at 573°3 C. to 1,500° C.

The Bureau's polarimetric measurements are the first precision measurements ever made at high temperatures, and a new line of attack for many unsolved problems is therefore opened. It is a matter of great theoretical importance that a mere regrouping of the atoms in a crystal can result in such profound changes in its physical properties.

Magnetic Rotation of Quartz at High Temperatures.

When a plate of crystalline quartz is placed between the poles of a magnet it rotates the light passing through it, the rotation due to the magnetic field being superimposed on the natural rotation. The magnetic rotation at high temperature has been successfully investigated by placing the furnace containing the quartz plate between the poles of a large magnet. In contrast to the remarkable changes in the natural rotation of the quartz as the temperature rises, the magnetic rotation is found to be practically independent of the temperature, increasing very slightly as the temperature rises and showing not the slightest effect due to the regrouping of the atoms which occurs at 573° C. The establishing of this fact is of much importance in modern electrical theory.

Standard Samples.

During the past year 64 standard samples of sucrose and 11 samples of dextrose were distributed. These materials are used principally for industrial and scientific purposes, such as the standardization of saccharimeters, for the determination of the heat value of coal and as standards in sugar analysis.

Pure Sugars for Miscellaneous Purposes.

Sucrose has been issued by the Bureau as a standard sample for several years. Being pure carbon, it is widely used as a calorimetric standard in the analysis of coal on account of its high purity and its accurately known fuel value. It is also used as a saccharimetric standard, as a source of pure invert sugar for standardizing sugar analysis, and for other miscellaneous purposes. Similarly dextrose (or glucose) in highly purified form has been issued as a "reducing" sugar standard for use in sugar analysis.

In response to a request from the Army Medical Supply Depot, we have supplied a quantity of our purified dextrose for use in differentiating bacteria of the colon group. This material is not at present obtainable to a satisfactory degree of purity on the general market and we are preparing either to supply it in the necessary quantities or to assist outside manufacturers to prepare it.

One manufacturer has submitted a sample of his purest dextrose for test. While his product still contains considerable impurities, it is hoped that slight improvement in his process will yield a product of sufficient purity for this and other purposes.

It is very desirable that other members of the sugar group be added to the list. They are useful in chemical work and in the differentiation of bacteria. Considerable progress has been made in the production of levulose, a sugar occurring in honey and fruits;

but none of the others have been prepared in pure form by the Bureau.

Influence of Temperature on Speed of Inversion of Sugar.

This investigation begun in the previous fiscal year has shown the exact time required for complete inversion of sugar at each temperature. By "inversion" is meant the transformation of sugar by means of acid into a mixture of dextrose and levulose which has a definite rotation in the polariscope in a direction opposite to that of sucrose. These measurements have shown that the time used in practice is very greatly in excess of that required. During this excessive time the inverted sugar suffers a serious decomposition in the presence of the acid. This preludes the possibility of accurate analysis. As a result of these experiments a new procedure is being developed and an accurate measurement is being made of the rotation of inverted sugar. In these measurements the decomposition of invert sugar is avoided as far as possible.

A determination of the rotation of invert sugar is being made not only at 20° C., the standard temperature, but also at the higher temperatures 28–31° C., which prevail in climates where cane sugar is produced. The importance of this investigation arises from the fact that upon it are based the data for devising the method of analysis of the sugar mixtures which occur in sugar manufacture.

Solubility of Dextrose.

The Bureau has assisted manufacturers in the preparation of pure dextrose by suggestion and by examination of their product. In view of the importance of encouraging the production of the pure sugar, solubility in water has been investigated, since a water solution is always the starting point from which the substance is purified. From these experiments it appears that the solubility increases rapidly with increasing temperature up to about 35°, at which point there is an abrupt change in the crystalline form and a resulting change in the relation of solubility to temperature. These measurements will be carried out at still higher temperatures and complete data on the solubility obtained.

Magneto-Optical Properties of Magnetic Substances.

Research has been continued on the magnetic rotation of metallic films, namely, iron, iron oxides (hematite, magnetite, etc.), and nickel, from room temperature to temperatures as high as 1,000° C. in some cases. This work is the first study of magneto-optical phenomena ever made at high temperatures. The behavior in this region of the substances mentioned is of great theoretical importance, existing theories having been based on the experimental facts observed at ordinary temperatures. The experimental difficulties which had to be overcome were described in the last annual report.

The results obtained now show that the magneto-optical effect (rotation of the plane of polarization of polarized light) for all the magnetic compounds so far studied, becomes zero at temperatures at which their ordinary magnetic properties are lost. This effect is especially clear in the case of nickel, the rotation falling abruptly to zero at about 360° C., the temperature at which nickel loses its magnetism.

In the case of iron the phenomena are much more complex. As soon as the temperature rises above room temperature, the magnetic rotation begins to decrease rapidly. It rises again somewhat at about 300° C., indicating that some change or transformation in the material is taking place, then falls off again gradually to practically zero at about 780° C., the A_2 transformation of iron.

In the case of hematite, the phenomena are even more complex and at present unexplainable. The rotation for some wave lengths is negative and for others positive. In some cases the rotation is negative at room temperature, becomes zero at about 400° C., and diminishes to practically zero again at 700° C. It remains zero up to 800° C., which was as high as these observations were carried.

Another peculiarity discovered in hematite is that it acquires a "set" in the magnetic field—i. e., after the field is removed the hematite film still shows a rotation, whereas it did not before putting it in the field. The direction of this "set" is changed with the change of direction of the field. It would appear at first sight as if an optically inactive substance were transformed into a naturally active one by placing it for a moment in a magnetic field. This phenomenon is undoubtedly connected up with the residual magnetism of the film as the "set" disappears at about the same temperature (about 400° C.) that the hysterisis of hematite disappears. The field required to reverse the set is about 5,000 Gauss.

Solubility of Sugar and the Causes of Molasses Formation.

Nearly 15 per cent of sugar obtained from beets and cane is lost to the production of granulated sugar in the form of "exhausted" molasses. Exhausted molasses is a solution of sugar, and the non-sugars occurring in the juices from which no further sugar can be obtained by crystallization. It is therefore of practical as well as scientific importance to ascertain the causes of molasses formation. This investigation, which was begun in the previous fiscal year, is proceeding along two principal lines.

First, experiments are being conducted upon the molasses themselves. We are endeavoring to ascertain whether all molasses act in a similar fashion in inhibiting the crystallization of sugar and in what respects the molasses from different locations differ. The behaviors of the two great classes, namely beet and cane molasses, are being compared.

Secondly, the effects of single pure constituents of molasses are being studied from the standpoint of pure physical chemistry, for the purpose of ascertaining what occurs within a solution containing pure sugar and a pure salt in a very concentrated solution.

Some of the theories which have been proposed to account for the formation of molasses already appear to require modification. From what has been already accomplished it now seems probable that the most promising line of attack of the problem of the prevention of excessive molasses formation is an exhaustive study of the complicated chemical reactions involved.

Intense Monochromatic Light Sources.

In connection with the work in polarimetry it has been necessary to secure sources of intense monochromatic light for colors which have heretofore not been available. To this end considerable effort

has been expended upon the production of cadmium amalgam lamps and after much experimenting a lamp using a new alloy has been produced, which promises to open up a new field of investigation.

Constants of the Quartz Wedge Saccharimeter.

The quartz wedge saccharimeter is used almost universally in the analysis of sugar. In Scientific Paper No. 268 the Bureau has described its standardization of pure sugar at the 100 per cent point on the scale. In order to place this standardization beyond question it is proposed to corroborate it with many further measurements. For this purpose pure sugar has been prepared from very varied sources of supply and analyses made to prove the purity of the samples. Sugar from Cuba, Java, Peru, beet sugar from Colorado, and maple sugar from Vermont have all been brought to the highest attainable purity. Such measurements as have been made show that the substance is identical regardless of its source.

Besides those on the 100 per cent point on the sugar scale, some measurements have been made on the lower points in order to correct for changes in rotation due to the altered concentration of the solution.

In addition to sucrose, many other sugars are analyzed on the saccharimeter. In Scientific Paper No. 293 the weight of dextrose (i. e., the normal weight) required to give the same reading as 26 grams of sucrose was determined experimentally. Similarly measurements are in progress on the rotation of levulose. It is desirable that all the common sugars be purified and their normal weights be determined to correspond to the true constants of the saccharimeter.

Customs Laboratory at Savannah, Ga.

The installation of a customs laboratory at Savannah, which was started under Bureau supervision last year, has been completed and the laboratory has been in operation for several months. A Bureau type precision saccharimeter was secured by transfer of the instrument from the New York service. The new laboratory has been of the greatest assistance in collecting the revenue on the abnormally heavy southern shipments of sugar from Cuba.

Utilization of Discarded Polariscopes.

In view of the inability of sugar manufacturers and refiners to obtain polariscopes for use in the chemical control of their factories, it has been necessary for them to use old types of instruments. In many cases the basis of calibration of these polariscopes is different from the newer and recognized types. The Bureau has been consulted in regard to the use of these instruments and has been able to render considerable aid in this respect. The Bureau is continuing to repair and adjust discarded polariscopes for sugar manufacturers in an effort to remedy the existing shortage.

Polarimetric Testing.

During the year 644 cover glasses for polariscope tubes were tested for optical homogeneity. The abundant supply of cover glasses now available is due to the Bureau's efforts in assisting American manufacturers to produce a satisfactory product. It was most fortunate that the Bureau's efforts culminated in the first American-made cover glass just before the war started.

Polarimetric Tests of Raw Sugar.

In connection with the Bureau's supervision of the sugar testing in the Customs Service, Treasury Department, 1,533 exchange samples of raw sugar were tested. Approximately 50 per cent were direct polariscope determinations of the quantity of sucrose present and the remainder were tested for the per cent moisture in addition to the sucrose content.

Sampling of Molasses at Key West.

The changes in the method of sampling molasses in tank cars inaugurated by the Bureau a year ago have given improved results. The samples are now taken at Key West in transit to interior points and shipped to New Orleans for testing. This method was recommended to avoid the expense of installing and maintaining a laboratory at Key West.

Supervision of the Customs Laboratories of the Treasury Department.

During the past year the work incidental to the supervision of the customs sugar laboratories has been greatly increased. This may be attributed to two causes:

1. The heavy importations of sugar from the West Indies, due to the necessity for refining before shipping to Europe.
2. The abnormal routing of shipments due to scarcity of ocean tonnage.

The latter cause results in the unavoidable collection of considerable revenue at interior points of destination where poor facilities or, at best, only inadequate facilities are available for sampling and testing. Nevertheless, the work has been done with accuracy and reasonable dispatch. No protests have been carried into the courts by the importers. The work of assisting the Treasury Department in improving the equipment, personnel, and efficiency of its general customs laboratories has been continued.

Definitions and Specifications for Refined Sugars.

The work of preparing definitions and specifications for the commercial sugars has been continued. However, the progress made has not been as great as had been hoped. This is attributable to the fact that the problem is a far more difficult one than had been anticipated. In order to accurately separate and define the various grades, it will be necessary to resort to every assistance which science can produce. All antagonism on the part of the industry has been eliminated and it is hoped to have preliminary results within the year.

Standard Glassware for Customs Service.

The work of interesting American manufacturers in the production of suitable chemical glassware for the Customs Service has been continued. Good results have been secured on some articles, but in the case of others the results have not been satisfactory. It is now believed that in normal times the service will be able to entirely discard European-made chemical ware for this work.

Bureau of Standards Baumé Scale.

The new Bureau of Standards Baumé scale has already resulted in the elimination of much of the confusion and misunderstanding which has been prevalent relative to density determinations in in-

dustrial work. It is based on the specific gravity values of Plate, on a working temperature of 20° C. and on the modulus 145. It is therefore adapted to the most convenient range of laboratory working conditions and the best available scientific data. Its immediate adoption in industrial sugar work and by scientific investigations has been gratifying. The Bureau has received a number of communications commending its action in this matter.

Basis of Saccharimeter Standardization.

In the last annual report attention was directed to the Bureau's work on the 100° sugar point of the saccharimeter, showing that the better grades of sugar tested over one-tenth of a per cent lower than they should. Since under present conditions it seemed hopeless to secure a correction of this error by international agreement, the Bureau has begun the standardization of saccharimeter and quartz control plates for the industry on the corrected basis. A report of the Bureau's work was submitted to the Secretary of the Treasury, who then requested the Bureau to restandardize all the quartz control plates in the Customs Service. This has been done, with the result that the Government's revenues from imported sugar have been increased by $60,000 a year. It is now planned to issue a circular letter to all owners of saccharimeters and control plates who have had their apparatus tested by the Bureau on the old international basis, apprising them of the error and of the necessity of correcting it.

Testing of Imported Molasses.

The importation of molasses, principally from the West Indies, has continued to increase and the value of the product per gallon has been enhanced from 100 to 300 per cent. The average polariscopic test shows less than 40 per cent sugar is present.

When the molasses schedule in the tariff act of 1913, in force at present, was drawn, the product was nearly worthless and an ad valorem rate of 15 per cent was fixed. Molasses testing over 40 was assessed 2¼ cents per gallon.

The recent rapid increase in value has therefore brought about a very anomalous situation, in that the low-grade product testing under 40 must pay a higher rate of duty than the more valuable product testing over 40.

There has resulted considerable difficulty in the customs laboratories in satisfactorily testing the low grades. The methods in force do not give the precision necessary to meet the situation. The bureau has begun preliminary work on this important problem and is cooperating with the customs laboratories to find a satisfactory solution.

COLORIMETRY.

(Measurement of the factors determining color; standardization of units, methods, and instruments used in colorimetry; development of primary and secondary standards of color, and their applications to the special industries; determination of color composition of light sources, relative color transmission, and reflection of constituent colors; the practical definition of color by formula; and the development of instruments for color measurement.)

Colorimetry.

Colorimetry is the measurement of the factors which determine or serve to specify color. Color is strictly and properly defined as a sensation; but the color of a light source may, nevertheless, be logi-

cally defined as the sensation produced by the light from that source, and likewise the color of an object as the sensation produced by the light transmitted or reflected by it. The fundamental physical basis of colorimetry is spectrophotometry, the measurement of relative emission, transmission and reflection for light of different wave lengths. Color may also be empirically specified by reference to arbitrary colored standards. The work comprised in this section deals generally with light sources, the transparency of materials, and the transmission, reflection, and diffusion of light and other radiant energy by materials. In some problems where color itself is not the prime consideration, still the measurements required and instruments and methods used are identical or similar. Such problems are therefore dealt with in this section. This work is closely related to and interlocks with other sections of the bureau's work, viz, photography, photometry, and radiometry. Its methods find practical application in chemistry, ceramics, pyrometry, and the testing of textiles, paper, paints, dyes, oils, and other materials, and in specifications and regulations concerning railway and other signals and eye-protective glasses.

Color-Standards Investigation.

The color-standards investigation mentioned in last year's report (p. 86) has been continued, although greatly impeded by the necessary diversion of effort to urgent military work.

The demand for color standardization mentioned in previous reports continues to be insistent. While the fundamental principles of the subject are fairly well understood by a few experts who have given particular attention to it, the practice of color specification is in a very unsatisfactory and indeed chaotic state. This condition is due to the following circumstances:

Lack of agreement as to standards, definitions, nomenclature, and methods, even among those experts who are competent to deal with the subject.

The failure of those most vitally interested in the subject from a practical and commercial point of view to comprehend at all the fundamental principles involved, i. e., a lack of clear concepts by those most interested.

The widespread current use, without standardization, of pseudo standards and empiric methods having no definition or even description other than their maker's or originator's name.

The lack of reliable quantitative data on the fundamental physical, physiological and psychological constants and factors involved.

The lack of well made precision instruments suitable to make the measurements requisite for color specifications.

The purpose of color standards investigation is to provide for the correction of these conditions. The work which the Bureau can do and has already begun can be considered as follows:

1. Experimental work.—A. Development of instruments and methods for general fundamental work; B. Determination of fundamental data and establishment of working standards; C. Application of spectrophotometric and colorimetric methods to specific technical purposes; D. Routine tests.

2. Organizing and educational work.—A. Cooperation and discussion with experts outside the Bureau for the purpose of develop-

ing and establishing uniform nomenclature and standards; B. Compilation and coordination of previous data. preparation of tables, graphs, etc.; C. The giving of information by correspondence, conference, and circulars.

Extension and Improvement of Spectrophotometric Methods.

The fundamental physical requirement for placing color standardization on a secure and reliable basis is the permanent installation at the Bureau of apparatus for convenient, accurate, and rapid spectrophotometric work by intercompared methods of testing of known precision and reliability. Visual spectrophotometric work has been in progress for several years. Its shortcomings were pointed out in the report for 1916 and plans for improvement and extension mentioned. These improvements and extensions have now been largely accomplished in that the apparatus for determination of spectral transmission by photo-electric and also by photographic means has now been installed and is in actual use. Both of these provide for accurate determinations of transmission for blue, violet, and ultra-violet light; and the photo-electric has been used throughout the greater part of the visible spectrum to wave lengths as great as 600 millimicrons. The photo-electric apparatus has also been used to measure reflection and plans are being made to adapt the photographic to the same purpose. An improved illumination apparatus for transmission and reflection has been designed for use with the König-Martens visual spectrophotometer. Its construction in the Bureau instrument shop was nearly completed at the close of the year. The three methods now in use supplement each other admirably and give gratifying check results. It is intended, however, to study much more carefully the comparison of results and the accuracy of each of these methods. This will involve a great deal more detailed work.

Collection of Specimens of Measured Spectral Transmission.

The systematic classified collection of marked and identified specimens of colored glass has been greatly increased and numerous determinations of the spectral transmission made by different methods.

Standardization of Nomenclature and Forms.

Considerable time and attention has been given to the careful selection and definition of numerous technical terms for our own use and to the standardization of forms and symbols for expressing results. This is preliminary to a hoped-for more general agreement on such matters of form and convention. After further consideration and discussion with others it is expected to incorporate such material in a Bureau circular. This matter has already been brought to the attention of the Illumination Engineering Society.

A Precision Method for the Production of Artificial Daylight.

One of the primary requirements for the establishment of color standards is the experimental realization of artificial light of the same spectral energy distribution as average daylight. For commercial purposes this has been more or less satisfactorily accomplished by others heretofore by screening artificial light sources with blue glass. While these glasses find an important and wide use commercially they do not give a perfect reproduction of daylight and are not

suitable for all purposes of precise specification. As mentioned in the report for last year, the Bureau has developed a novel method of reproducing daylight by means of the rotatory dispersion of quartz. A description of this method with explicit specifications for producing the desired results has now been published. This method will be of basic importance in the establishment of color standards, but it is intended solely for precision work with instruments, and is not a commercial competitor with the blue-glass method. Its scientific advantages over the latter are: (1) A much more accurate reproduction of the desired spectral energy distribution; (2) certain and convenient reproducibility and definiteness of specifications; (3) convenient adjustability.

The Specification of the Color of Light from the Ordinary Light Sources and the Photometry of Lights of Different Color.

The development of methods and apparatus for this purpose was mentioned in the last annual report. Since then another paper further explaining and substantiating these methods has been published. By request of the Cooper Hewitt Electric Co., preliminary experiments on adapting this method to the photometry of mercury vapor lamps have been made; but it has been necessary to temporarily discontinue this on account of the urgency of military tests and investigations.

The Color Grading of Cottonseed Oil.

This investigation which has been in progress for several years has been almost entirely dropped for the present to give place to military work. Otherwise it could have been brought to a satisfactory conclusion. This necessity is greatly regretted, and it is hoped to take up this work again at the earliest opportunity.

Determination of the Spectral Transmission of Standard Pure Dyes and Other Materials.

This work is of immediate importance in order to put dye standards on a secure and reliable basis for the purposes of trade and the assessment of customs by the Government. There is now little or no reliable quantitative data available on this subject. Our own work on it is only beginning, and its proper and satisfactory early completion will require considerable increase in space and personnel. The commercial importance of this work would seem to warrant the additional expenditure required. The Bureau is now in possession of a large collection of important prewar German dye samples. Arrangements are being made to secure other pure standard samples and commercial samples of American manufacture. The necessary elaborate and expensive apparatus for making the determinations is already provided and installed at the Bureau, and the extensive series of determinations required will be undertaken during the coming year. It could be greatly expedited by an additional appropriation of about $5,000.

Cooperation with Societies and Organizations.

It is the Bureau's policy to cooperate and maintain close relations with technical organizations interested in the work in progress at the Bureau. By invitation, the Bureau's expert in charge of colorimetry has contributed a paper describing its work on color standardization to the Transactions of the Illuminating Engineering Society. This

section of the Bureau was represented at the New York Dyestuff Convention, January 22–23, 1918, and has been represented on committees of the Illuminating Engineering Society, the National Research Council, and the Society of Cotton Products Analysts.

Examination of Glasses Intended to Protect the Eyes from Harmful Radiation.

This investigation mentioned as in progress in the last annual report has been completed and a Bureau of Standards technical paper on it is now in course of publication.

Investigations on Color, Visibility, and Related Subjects for the Military and Naval Authorities.

By far the greater part of the time and effort of this section during the year has been given to work of a military nature. This work has continually increased until at the close of the year it required attention to the almost complete exclusion of other matters. Routine military tests are reported in another paragraph. Besides these, several reports on extensive confidential investigations have been made.

Investigations of the following kinds were in course at the close of the year, but no extensive reports had been issued: Color of searchlights; chromatic camouflage; color specifications for signal flares.

Colorimetric and Related Optical Tests.

Formal reports have been made on the color, spectral transmission, reflection, or transparency of 95 separate specimens or samples submitted for test. These include various colored glasses, eye-protective glasses, colored signal glasses, camouflage material, tracing cloth, binoculars, photographic paper, etc.

By far the greater number of such tests during this year have been of a military nature. There has been a notable falling off in the number of civil and commercial tests. This has been due in part to fewer applications and in part to the military necessity of declining to undertake some commercial tests applied for. Of special note among the military tests, because of its somewhat exceptional nature and the urgency with which the results were demanded by the Signal Corps, was a test of the spectral transmission of binoculars. The bureau was informed by the Signal Corps that the acceptance of several thousand urgently needed binoculars would result from the report on this test.

The following table shows the number of submitted specimens tested for various applicants:

Military Tests.

War Department:		
General Engineer Depot	16	
Office of Chief Signal Officer	12	
Chief of Ordnance	9	
Total, War Department		37
Navy Department and United States Navy:		
Bureau of Steam Engineering	8	
Washington Navy Yard	6	
United States Naval Hospital	5	
First Naval District	3	
Bureau of Construction and Repair	2	
Total, Navy Department		24

National Research Council (military work)	9
Total of military nature	70

Civil Tests.

Civil departments of the United States Government	22
Railway	2
Manufacturer	1
Total of civil nature	25

Information, Advice, and Assistance on Colorimetric and Related Optical Questions and Problems.

Besides the preparation of definite reports on tests and investigations mentioned above, a great deal of time and effort has been given to complying with requests for information, assistance, and loans of materials or apparatus. This service is rendered partly by the preparation of letters in reply to inquiries and partly by personal conference. During the past year these questions have been largely of a military nature.

Information, Advice, and Assistance Rendered the Army and Navy and Other War Agencies of the Government.

Assistance has been rendered the war agencies of the Government by furnishing desired information, supplying or loaning materials, and affording laboratory facilities for cooperative experimental work. These services may be briefly enumerated in part as follows:

For the office of the Chief Signal Officer, War Department: Information concerning the ultra-violet transmission of several glasses has been furnished to the Balloon Section. Information concerning camouflage material and color screens (ray filters) has been given to the Science and Research Division. Some of the personnel of the same division have been afforded laboratory facilities and various color screens, mirrors, crystals, etc., have been provided for their use elsewhere. For the General Engineer Depot, United States Army: Laboratory facilities have been provided for cooperative work on the spectral distribution of the light from searchlight arcs. For the Quartermaster's Corps, United States Army: Information in regard to chromatic camouflage. For a company of Engineers, United States Army: Officers and men of this company have been given information and advice on color measurements, chromatic camouflage, color screens, etc. For the American University Experiment Station: Advice in regard to color measurements and specifications. For the National Research Council: Information in regard to ultra-violet photography. For the National Advisory Committee for Aeronautics: Information in regard to chromatic camouflage. For the Navy Department: Information in regard to chromatic camouflage, signaling, searchlights, visibility under water, and transmission and diffusion of light by certain glasses has been given. Special anticamouflage screens have been made and provided. Apparatus and instruments requiring weeks of work have been designed and constructed for certain confidential investigations. For the United States Shipping Board: Information and advice on chromatic camouflage and color specifications.

Information and Advice to Applicants Representing Scientific, Commercial, and Industrial Interests.

The following list summarizes in a general although incomplete way the kinds of information given, together with representative names of the applicants who requested it:

1. Concerning colorimetric and photometric apparatus and methods of measurement and their application to specific problems: Bureau of Plant Industry, Department of Agriculture; United States Tariff Commission; Johns Hopkins University; American Writing Paper Co.; Williams, Brown & Earle; New York Butter Packing Co.; Max Levy; Cooper Hewitt Electric Co.; American Lithographic Co.; Forbes Lithographic Co.; Eimer & Amend; E. I. Du Pont De Nemours Co.

2. Concerning colorimetric definitions, standards, charts, etc.: Artificial Daylighting Co.; Supreme Council Thirty-third Degree Masonry, Southern Jurisdiction; Hon. Clifford Ireland, et al.

3. Concerning colored signal glasses: Navy Department; Bureau of Lighthouses: Pennsylvania Railroad.

4. Concerning methods and standards for color-blindness testing: Sante Fe Railway.

5. Concerning eye-protective glasses: United States Patent Office; F. A. Hardy Co.; safety experts and commissions.

6. Concerning the ultra-violet transmission of certain glasses: Pennsylvania Wire Glass Co.; Corning Glass Works; Vernon M. Dorsey.

7. Concerning colored glass for use in illuminating of telescopic micrometer: United States Naval Observatory.

Determination of Thermal Expansion by Interference Methods.

The thermal expension of small samples from 1 to 20 millimeters long is determined by methods using the interference of light waves. All the necessary apparatus has been completed for making thermal expansion determinations from liquid air temperature to 1,000° C. During the year tests have been made upon glass for searchlight reflectors, standard gauges, fused quartz, optical glass in connection with the optical glass investigation, and aeronautical instrument alloy.

Gauge Calibration by Interference Methods.

Interference methods for determining the planeness, parallelism, and length of standard gauges have been devised and used. Two sets of gauges ranging in length from 0.05 meter to 4 inches have been calibrated in terms of standard light waves. Further investigation in connection with manufacturers of standard gauges is in progress.

Index of Refraction of Gases and Saturated Vapors.

The work started last year on the index of refraction and dispersion of air has been completed. In order to make the necessary corrections for the humidity of the atmosphere, the index of refraction of saturated water vapors was measured for the temperature range —10° to 103° C.

A special fused quartz interferometer and pyrex glass container were built for this work. Using the same apparatus the index of re-

fraction and dispersion of the saturated vapors, ammonia for the temperature range −50° to +27° C. and ethyl chloride for the temperature range −50° to +50° C. were measured. One of the objects of this work is to find an accurate and rapid method for determining the density of saturated vapors.

OPTICAL INSTRUMENTS.

(Design of optical instruments; testing and research on optical systems, optical instruments, and appliances such as telescopes, binoculars, cameras, gun sights, and the like, and optical parts such as lenses, prisms, mirrors, parallel plates, etc.)

Airplane Camera.

The design of a new airplane camera using film was begun last year. This camera uses a lens 37-inch focus and takes pictures on film 8 inches square. The capacity of this camera is 75 to 100 pictures at one loading. An additional feature in this camera is the simultaneous photography of several auxiliary instruments on a corner of the film, furnishing desirable information in connection with identification and interpretation of the picture.

Projection Lens.

Due to the great demand for instruments for military purposes, all available manufacturing facilities were impressed into war work. Such industries as use projection lenses found themselves unable to obtain any, and were forced to make plans for manufacturing these lenses. One lens was measured and the construction data supplied to a company, enabling them to make their own lenses.

Instruments for Navy.

A small telescope for use with stadimeters was designed for the Navy and is now being turned out in quantity.

The constants of a gunsight telescope, which will eventually become the standard for the Navy, were measured and work begun to adapt the design to available glass. Further work of this kind will be carried on with other telescopes as the needs arise.

Long-Range Photography.

For purposes of photographing at great distances and obtaining a visible picture, lenses of rather long focal length should be used. Three types of lenses were tried for this work, and experiments are being carried on to determine the best type for the purpose.

Testing of Optical Systems and Glass.

Several hundred optical instruments, comprising binoculars, gun telescopes, periscopes, range finders, camera lenses, etc., were tested for the Army, Navy, Emergency Fleet Corporation, and various manufacturers. Practically all of the instruments were made in America, with optical parts of American-made optical glass, and it is gratifying to observe the high standard of perfection which these products have now attained.

Binoculars.—Auxiliary to the acceptance tests of field glasses, more searching tests have been made of the optical constants of many binoculars. For this work it has been necessary to develop testing methods which enable the tests to be made accurately and quickly. Some of the tests may be made by relatively unskilled persons after a short period of training, but one or two of the tests are difficult to

simplify to this extent. The methods devised are being applied to acceptance tests.

Camera lenses.—A number of camera lenses have been given thorough tests, with special reference to their use for specific military purposes. A large number have been measured for equivalent and back focal lengths. The change in focal length with temperature was investigated to temperatures as low as —35° C. and found to be small.

Military Telescopes.—A number of military telescopes of various types have been examined and the constants of the instruments determined for both the Army and the Navy Ordnance Bureaus. In general, information as to light transmission, definition, field of view, and magnification is desired.

Miscellaneous Tests.—Other tests than the ones referred to above have been made of the constants and quality of lenses, lens systems, and instruments. These tests have mostly been for military bureaus.

Optical Glass Constants.—The index of refraction, dispersive constant, and transmission of many samples of optical glass have been measured. These data have been mostly for Bureau of Standards glass, but a number of determinations for other glass have been made.

In addition to these routine tests a number of determinations of indices for special purposes have been made.

A list of the tests referred to above follows:

OPTICAL GLASS AND INSTRUMENT TESTS.

Binoculars.

For Signal Corps	315	
For Naval Ordnance Bureau	35	
For General Engineering Depot	14	
For Shipping Board (acceptance tests)	729	
Special tests	120	
		1,213

Military Telescopes.

Gun sight telescopes	14	
Range finders	3	
		17

Lens Systems.

Photographic lenses:		
Complete tests	17	
Focal lengths	50	
Radii	4	
Temperature change of focal length	5	
Special tests	1	
Other lenses:		
Focal lengths	20	
Radii and constants	1	
Condenser lenses:		
For striæ	152	
		250

Optical Glass.

Indices of refraction and dispersive constants	278	
Transmission	183	
		461

Miscellaneous.

Lens test plates, pairs for radii of curvature	16	
Refractometer	1	
Goggle lens frames	60	
		77
		2,018

Circular on Optical Instruments.

In response to numerous requests for general information on optical instruments a new circular on The Properties and Testing of Optical Instruments has been prepared. In this circular the important characteristics of different types of optical instruments are discussed in an elementary way and methods of testing the performance of such instruments are described.

Optical Glass.

Production.—The experiments in optical glass manufacture have progressed very favorably during the past year. The Bureau of Standards is shipping glass in quantities for the manufacture of optical instruments and the glass is of a very good grade.

Quality.—Some large lenses of a high relative aperture, made entirely out of some of the earlier melts of Bureau of Standards glass, performed excellently. The absorption of the glass is small, being regularly less than 1 per cent per centimeter in the case of the prism flint glasses, and, with the exception of the heavy barium crown glass, seldom running over 2 per cent.

Types of Glass.—The Bureau of Standards is producing glass of the following types:

Kind of glass.	n_D.	ν.
1. Light crown	1.518	60.0
2. Barium crown	1.574	57.5
3. Light flint	1.580	42.0
4. Prism flint	1.55	50.5
5. Medium flint	1.621	36.5
6. Dense flint	1.655	34.4
7. Dense barium crown	1.610	57.0
8. Borosilicate crown	1.517	64.0

Glass for Photographic Lenses.

The bureau has been successful in producing dense barium crown glass of a usable quality. The light absorption of this glass is still greater than is desirable and there are also more bubbles than could be wished, but the color is good and the glass is free from stones. The index of refraction of different melts varies somewhat, but an improvement in this direction is looked for.

Methods for Testing Optical Glass.

Successive improvements in methods of examining optical glass for bubbles, stones, and striæ have been made during the year.

Optical glass is usually molded in flat slabs, polished on the edges, and is then examined between these two polished faces for bubbles (seed), stones, and striæ. The same examination may be made without polishing, by grinding the edges and then placing cover glasses

against the ground faces, using a few drops of oil between the cover glass and the ground surface. Somewhat more conveniently the piece of glass may be placed in a tank containing a mixture of carbon bisulphide and gasoline of the same index of refraction as the glass. In this method of examination monochromatic light may be used to advantage, and this method is now in use at the Bureau of Standards glass factory. This method has been used with success in testing many small unworked pieces which would otherwise have been discarded for lack of such examination.

The Effect of Striæ in Optical Glass.

An investigation of the effect of striæ upon the performance of lenses and prisms has been undertaken and some progress has been made. The investigation has proceeded far enough to show that the presence of light striæ in moderate amounts does little harm to the image formed by an optical system. This has been demonstrated by tests on many binoculars and on a number of lenses and prisms containing striæ, some of them in amounts great enough to badly impair the image.

Corrosion Tests.

Methods of investigating the weathering and hygroscopic properties of optical glass have been developed and a great many tests have been made to compare the permanency or resistance to corrosion of different types of optical glass from various sources. Gratifying success has been attained in producing optical glass whose surfaces will not disintegrate.

Circular on the Testing of Optical Glass.

For the general use of manufacturers and consumers of optical glass a circular entitled "Testing of Optical Glass" was prepared and distributed. An effort was made to define and explain methods of measuring the desirable properties as well as to describe tests for the detection of common defects in optical glass in such a simple form as to be of assistance in the production of better glass for optical use. The revision and extension of this circular is contemplated.

Nonshatterable Glass.

At the request of the National Advisory Committee for Aeronautics, an investigation was made of the so-called nonshatterable glasses intended to protect the eyes from splinters when accidents occur which fracture the glass used in spectacles, aviator goggles, face masks, wind shields, etc. It was found that the relatively increased nonshatterability of laminated glass and its comparatively good transparency and rigidity even after puncture, give it great importance in devices for protecting the eyes and face.

RADIOMETRY.

(Development of standard instruments and methods of measuring thermal radiation, commonly designated ultra-violet, visible, and infra-red rays; determination of the reflective, absorptive, and emissive properties of materials for thermal radiation; development of standards of thermal radiations; determination of radiation constants; and the measurement of thermal radiation in absolute value.)

Radiometry.

In the general subject of radiometry, investigations have been continued in connection with the improvement of instruments for

measuring weak radiations, using selective radiometers. Considerable time was spent on military work involving radiometry. For this reason the investigation of the radiation constants have been in abeyance.

One of the subsidiary problems undertaken was the adaptation of the Callendar sunshine receiver and the sliding mechanism of the recorder to the diaphragm opening of a camera, which is to be used in obtaining a series of exposures at frequent intervals throughout the day. By connecting the diaphragm with the sliding arm of the recording mechanism the to-and-fro motion of the latter regulates the diaphragm opening of the camera and hence the amount of light reaching the photographic plate.

The incandescent lamps, used as standards of radiation in absolute value were intercompared, and a set of two lamps were standardized for a well known research laboratory. These lamps give the radiant flux per square millimeter area, in absolute value, at a distance of 2 meters from the lamp. They were prepared some years ago by direct comparison with a black body on the basis that the coefficient of total radiation is $\sigma=5.70$, which is close to the value $\sigma=5.72\times10^{-12}$ watt cm^{-2} deg^{-4}, recently determined by this Bureau.

Among the subsidiary investigations was a determination of the spectral reflecting power of a series of magnalium alloys.

Life Tests of Quartz Mercury Vapor Lamps.

The ultra-violet, as distinguished from the infra-red rays, appear to have a marked effect in accelerating chemical action, as for example, in the fading of dyes. There has arisen among manufacturers of paper, dyes, cloth, rubber goods, paints, etc., a need of information concerning sources, and their constancy of emission, of ultra-violet radiations, for use in testing the lasting quality of their products.

It is well known that the intensity of the radiation (especially the ultra-violet component) from quartz mercury vapor lamps, decreases greatly with usage.

In response to the demand for exact data, during the past year methods were devised for determining quantitatively the decrease in intensity of emission with usage, and measurements were made on radiant-power life tests of a number of quartz mercury vapor lamps.

The data obtained indicate a marked decrease in the total radiation, as well as the ultra-violet component, emitted in the course of 1,000 hours' usage of the quartz mercury vapor lamps now obtainable on the market.

Optical Properties of Balloon Fabrics.

In connection with the general investigation (chemical, mechanical, etc.) of this subject, the transmissive and reflective properties of numerous samples of balloon fabrics was determined, using a hemispherical mirror and thermopile, mentioned in previous reports. Measurements were made also of the rise in temperature when the fabrics were exposed to solar radiation, using a modification of the fine thermocouples mentioned in the report of 1916. The investigation is being continued on a small-sized model balloon.

Photo-electric Properties of Various Substances.

This is a continuation of the investigation mentioned in last year's report. The photo-electric sensitivity of several substances is being determined, for equal energy values, in different parts of the spectrum.

Extensive data have been obtained on the spectral photo-electric sensitivity of molybdenite as affected by temperature, intensity of the stimulus, humidity, etc. For certain radiometric investigations, samples of molybdenite, which are photo-electrically sensitive, may be used instead of a selenium cell.

Infra-Red Transmission Spectra of Various Substances.

The spectral transmission of various substances, including special glasses, colored fluorite, etc., was determined, and the data are now in press.

Some of the glasses examined have narrow spectral bands of high transmission, which renders them useful as transmission screens for infra-red photography and for producing bands of fairly homogeneous radiations without employing a spectroscope.

Glasses for Protecting the Eyes from Injurious Radiations.

In last year's report attention was called to the importance of this subject and that radiometric measurements are the logical basis upon which to specify what constitutes ample protection from ultra-violet and infra-red radiations.

During the past year considerable new data were obtained on the ultra-violet and infra-red radiations transmitted by various glasses used for spectacles. The sources of radiation used were typical of those to which one is exposed in occupational pursuits. For example, the quartz mercury vapor lamp and the magnetite arc, used in these tests, were representative of sources of extremely intense ultra-violet radiation, while the gas-filled tungsten lamp and the sun represented high intensities in the visible and infra-red spectrum. These new data were published in a revised and enlarged edition of Technologic Paper No. 93, Glasses for Protecting the Eyes from Injurious Radiations.

Information Furnished on Radiometric Subjects.

In reply to specific requests therefor information was given on various radiometric matters, such as, for example, the reflective properties of metals useful in searchlights, etc.; thermal-radiodynamic signaling devices; photo-electric substances; eye-protective glasses; the constancy and methods of standardization of sources of ultra-violet radiations of high intensity; emissivity of paints to be used for preventing the heating of certain kinds of electrical machinery; construction of iron-clad Thomson galvanometers; standard blackening of radiometer receivers; and various radiometric questions having a military application.

Publications on Radiometry.

During the past year the following papers on radiometry were published: Technologic Paper No. 93 (second edition, revised and enlarged), Glasses for Protecting the Eyes from Injurious Radiations; Scientific Paper No. 319, Instruments and Methods Used in Radiometry, III—The Photo-Electric Cell and Other Selective Radiometers;

Scientific Paper No. 322, Photo-Electric Sensitivity of Bismuthinite and Various Other Substances.

DISPERSOIDS.

(Investigation of the physical properties of dispersoids, such as smokes, water supplies, biological fluids, optical glass, etc.; preparation and specification of standard dispersoids; development and standardization of dispersoid constants, instruments, and methods of measurement; cooperation in the technical application of dispersoid information in other branches of Government, in science, and in the industries.)

Scope of Work on Dispersoids.

There is a large class of substances of technologic importance which possess in common the characteristic of containing in suspension another substance in a dispersed or finely divided state. All such media are called turbid or heterogeneous, and have been named dispersoids. A dispersoid is more complicated than a homogeneous material because it is always composed of two substances, the suspended particles and the medium in which they are dispersed.

Smoke, fog, condensation nuclei, dust, and powders are examples of turbid gases; water supplies, muddy rivers, lakes, and harbors, ocean turbidity, technical colloidal suspensions and emulsions, and biological fluids are important fluid dispersoids; optical glass, crystals for optical instruments, such as calcite, quartz, and fluorite, and opal or milk glass are solids in which turbidity is an important factor.

The measurement and standardization of the physical properties of dispersoids presents extremely difficult and technical problems. In studying dispersoids the optical properties have been most useful.

For several years the Bureau has been developing instruments and methods in order to standardize measurements in this field. For a quantitative measure of the light scattered by a dispersoid a turbidimeter has been designed and constructed; to measure the size of particle the microscope, ultramicroscope, and corona methods have been used, and to count the number of particles in gases condensation methods have been employed. The problems of evaporation, condensation, convection, diffusion, coagulation, settling, filtration, and the production of standard dispersoids have also been attacked.

This work is of wide application. A satisfactory standard of turbidity in water analysis is much needed in determining the efficiency of the filtration of municipal water supplies. Industrial processes such as tanning, dyeing, and the manufacture of paper involve dispersoids, the quantitative measurement of whose properties would make possible control and improvement. Biological fluids such as sera are already a commercial product of great importance for which a standard of turbidity is needed. Smoke and dust are produced in many industries, and many cities regulate the extent to which they may be discharged into the atmosphere. A more precise specification of such gaseous dispersoids would facilitate the administration of such laws.

SOUND.

(Research and testing upon sound sources, sound-analyzing instruments and appliances; investigation of the theory and methods of sound measurement.)

Sound Investigations.

The Section of Sound Investigation was started in the Bureau in August, 1917. An important part of the work of the year, therefore,

was the establishment of the section and the assembling of equipment for the work to be done. While the demands of military work necessarily took precedence at this time, the apparatus acquired is practically all of it such as has permanent value and usefulness for investigations of a general nature in the subject of sound.

A Koenig clock fork, the most refined instrument yet constructed for the exact measurement of vibration frequencies of tuning forks, has been secured and put into good running order in our shops. The most refined instrument for the measurement of sound intensity is Prof. Webster's phonometer. Prof. Webster has had one of these made for us in his own shop at Clark University, embodying all the improvements he has been able to work out for it.

One of the most promising inventions of recent years in its relation to sound, in addition to its great usefulness in wireless telegraphy, is the "audion" or "pliotron." It is especially interesting and useful by reason of the fact that it serves either as a maintainer or as an amplifier of oscillations. One of these tubes has been secured, and, together with the proper auxiliaries in the way of condensers, inductance coils, etc., forms an oscillator which promises, with suitable acoustic fittings, to furnish a more flexible, dependable, and exact source of sound than any hitherto available.

A good beginning has been made on a collection of tuning forks. Among these is a unique and valuable set of 37 forks covering the range from 523 to 4,186 vibrations per second (that is, three octaves) by semitones, made expressly for the Bureau at a nominal price by a Chicago manufacturer.

Besides these apparatus that have been secured from outside makers two forms of apparatus for sound analysis have been developed. The first of these is a set of "Reed phonometers" similar in principal to Webster's phonometer, but very much simplified, and used in considerable numbers, so as to give data for a number of pitches at once instead of only one. This forms a somewhat elaborate installation, so that for an easy and rapid, though less accurate, indication of the quality of a given sound, a form, again much simplified, of the "phonodeik" was devised and is being used with success.

The section therefore is now equipped with the best type of instruments for determining the three distinguishing features of sounds, namely, pitch, intensity, and quality or composition. It also has a good assortment of sources of sound and standards of comparison.

The work of the year, besides the acquiring and development of these apparatus, included cooperation in certain phases of the work done by members of the engineers of the Army on sound-ranging and advice and help in various problems arising in other sections of the Bureau or other departments of the Government involving the application of acoustical principles of apparatus.

A series of tests was made, in cooperation with the National Advisory Committtee for Aeronautics, of the effectiveness of several types of mufflers offered for gasoline engines. In these tests, which are still proceeding, both the Reed phonometer and the phonodeik are being used to find the effect of the muffler on the noise of the engine.

5. CHEMISTRY.

[Chemical composition and purity of material, chemical properties and constants, including researches upon methods of analysis, specifications for technical materials, and preparation of pure materials for standardization work for the Government and for industrial and scientific laboratories.]

Chemical Testing.

The number (18,365) of tests made in the chemical laboratories during the year is double that of the preceding year. Distributed by types of materials they were as follows: Ferrous metals (irons and steels), 2,309; nonferrous metals, alloys, and coated metals, 1,638; cements and cement materials, 5,870; coal tars, asphalts, saturated felts, burlaps, and building papers, 1,056; linseed oils, turpentine, driers, varnishes, and shellacs, 1,052; red lead, white lead, putties, graphite paints, and miscellaneous paint materials, 888; lubricating oils and greases, 649; soaps, nondrying oils, and metal polishes, 630; inks and ink materials, typewriter ribbons, sealing waxes, etc., 406; balloon fabrics, 895; rubber, 676; leather, 1,030; miscellaneous, including flax packing, asbestos, textile materials, etc., 1,266.

The above tests were made for very many Government bureaus and establishments and for States, municipalities, foreign and allied commissions, and private parties, as follows: Agriculture, 64; Commerce, 6,956; Interior, 95; Labor, 6; Navy, 564; Post Office, 294; Treasury, 1,666; War, 6,485; Panama Canal, 1,539; General Supply Committee of the District of Columbia, 406; other Federal institutions, commissions, and committees, 178; State, municipal, and other institutions and committees, 25; foreign and allied commissions, 44; private parties, 43.

By far the major part of these tests were made for the military branches of the Government. Much of the increase over the preceding year occurred in the last four months of the fiscal year 1917–18. If this increase is maintained over the year 1918–19, the number of samples to be tested may reach 30,000.

The New Chemistry Building.

The transfer of the chemical staff to the new chemistry building was completed in August of 1917, although the building still lacked certain important parts of its equipment. These have for the greater part since been installed, but the permanent electrical wiring remains to be done, as also the installation of the vacuum cleaning apparatus.

In consequence of the rapidly growing requirements of the military branches of the Government, the capacity of the building is already largely overburdened and the need for additional space elsewhere is imperative. Designed to accommodate a maximum of 120 workers of all classes, the building now housed on July 30, 1918, about 150. This crowding does not make for efficiency.

Chemical Publications.

The following papers emanating from the Chemistry Division were published during the year, or are nearly ready for publication: Scientific Paper No. 316, Gas Interferometer Calibration; Technologic Paper No. 98, Effects of Heat on Celluloid and Similar Materials; Technologic Paper No. 105, Comparative Tests of Porcelain Laboratory Ware; Technologic Paper No. 107, Comparative Tests of

Chemical Glassware; Technologic Paper No. 113, Determination of Permeability of Balloon Fabrics; Technologic Paper No. 118, Critical Study of the Ledebur Method for Determining Carbon in Steel and Iron; "Rapid Determination of Carbon in Steel by the Barium Carbonate Titration Method," Journal of Industrial & Engineering Chemistry, volume 10, page 520, 1918; "Investigation of Ladle Test Ingots, II," to appear in the Year Book for 1918 of the American Society for Testing Materials; "Causes and Remedy for Gas Formation in Ammonia Absorption Systems," Journal of the American Society of Refrigeration Engineers; "Toluol Recovery and Standards for Gas Quality," Journal of Industrial & Engineering Chemistry, volume 10, page 251, 1918; "Notes on the Color Designation of Oil Varnishes." Journal of Industrial & Engineering Chemistry, volume 10, page 475, 1918; "Investigation of Balloon Fabrics by the Bureau of Standards," Third Annual Report of the National Advisory Committee for Aeronautics.

PHYSICAL CHEMISTRY.

(Preparation and purification of materials required in investigation of physical constants, for example, refrigeration of materials, calorimetric samples, etc.)

Chemical Work on Refrigeration Problems.

A number of samples of pure ammonia and ethyl chloride were purified for the Heat Division of the Bureau for use in the determination of important physical constants. Methods of purification and testing previously used were perfected and tried out. The apparatus employed was also used in preparing pure gases for other purposes.

A method was devised for eliminating the formation of noncondensing gas in refrigeration systems using ammonia absorption, whereby corrosion is avoided and the saving of considerable ammonia is made possible. This work has been given considerable publicity by the Food Administration in its circulars to operators and owners of refrigeration plants in part of its campaign to conserve ammonia.

Purification of Materials for Special Purposes.

Samples of pure carbon dioxide and oxygen were prepared by fractional distillation (sublimation in the case of carbon dioxide). The boiling points of these two substances are to serve as fixed points in the reproduction of the low temperature scale, which is necessary for contemplated work on methane.

The purification of mercury has been placed upon a routine basis and it is estimated that nearly a thousand pounds of the metal was purified for the use of the Bureau.

A considerable quantity of pure methane was prepared for use in the determination of its physical constants by the Heat Division.

ELECTROCHEMISTRY.

(Electrodeposition, including electrotyping, electroplating, the latter including investigation of zinc, lead, nickel, copper, silver plating, etc.)

Electrotyping and Electroplating Investigations.

Owing to the increased demands for information on electroplating of military supplies, and to delays in the installation of equip-

ment, not much progress was made upon the study of electrotyping, even though the International Association of Electrotypers had engaged a chemist to assist in this work. Upon his resignation from this position in January the electrotypers were advised not to attempt to replace him at that time, owing to the demand for chemists for military work. Arrangements were then made for a bureau chemist to continue the experiments upon substitutes for Austrian ozokerite, as the product made from American ozokerite was apparently not satisfactory. Since then, however, the company controlling the domestic deposits has improved its product, which is now extensively used. There is therefore no pressing need for investigation of this subject, although cheaper substitutes might be devised through such an investigation.

The study of electroplating has been principally directed toward the formulation of specifications and definition of methods of operation and testing of military supplies. In general, this work forms a part of the general investigation of protection against corrosion, and is closely associated with the other phases of that investigation. Since it has been found that zinc coatings exert far better protection to iron and steel than do copper or nickel plating, or other forms of protective coating, special stress has been laid on the study of zinc plating. Owing to the extensive use of black nickel plating to produce a black finish upon military supplies constructed of brass or steel (previously plated with copper, or preferably zinc) the methods of black nickel plating are also being studied. The application of lead plating, especially on gas shells, is also being studied.

In view of the fact that there were almost no specifications or satisfactory tests to form a basis for the inspection of plating on military supplies, a conference upon this subject was held at the Bureau of Standards on March 27, 1918. Representative platers and manufacturers of plating supplies were present, as well as officials of the War and Navy Departments and of the Bureau of Standards. Definite recommendations were made, the most important of which were:

1. For protection of iron and steel against corrosion, only zinc coatings should be employed.

2. Where a black finish is required, the black nickel finish should be recommended.

A plating adviser was engaged on May 15, 1918. Since then he has made numerous visits to plants manufacturing military supplies, and has conferred with officials of the War and Navy Departments upon improvements in existing methods. In general, the cooperation and assistance of the Bureau of Standards in this work has been appreciated by the military officials, who have referred numerous plating problems to this Bureau. Among the classes of military supplies to which plating is or may be applied are, aircraft fittings for both land and sea planes, material used in the construction and equipment of vessels by the Navy Department and the Shipping Board, hardware and equipment used by the Ordnance, Quartermaster's, and Marine Corps (e. g., buttons, belt fittings, harness fittings, hardware for tents, ammunition boxes, etc.), fuses and other parts of artillery ammunition, magazines, and cartridge clips for rifles and machine guns, surgical instruments, tableware, and in general, almost

any supplies constructed of metal. So far as possible it is important to have the specifications and methods of testing such products uniform or at least consistent, since often a great variety of work is made or plated in the same plant.

The present equipment at the Bureau for semicommercial electroplating has proven useful not only for research work, but also for occasional plating of articles made in the Bureau shop. If, however, much of such work should be required, a separate small job plating plant should be installed, which might be operated under the supervision of this section. In either case it is desirable to install equipment for the grinding, polishing, and buffing incidental to plating. Since at present there is no suitable equipment at the Bureau for this work, such machinery should be selected with a view to meeting not only the research requirements, but also the probable needs of the Bureau in this line.

METALLURGICAL CHEMISTRY.

(Preparation of metals and alloys required in connection with metallurgical investigations and special methods of analysis for such products.)

Rapid Determination of Carbon in Steel.

The electrolytic method reported upon last year has been still further improved and simplified so that an accurate determination of carbon can be made in $4\frac{1}{2}$ minutes.

Means have been devised for increasing by 50 per cent, with only slight decrease in accuracy, the output of work when using the barium carbonate titration method for carbon in steel.

Determination of Gases in Steel.

Several experimental forms of apparatus were constructed and tried out for determining the nitrogen content of steel by the method of absorption by metallic calcium that was referred to in last year's report. One especially of these promises to give excellent service.

Further progress was made in the development of Goeren's method for determining gases in steel. Several practical applications of this method are indicated by recent metallurgical problems that have been brought to the Bureau by military branches of the Government and by commercial firms.

Further work on the Goutal method of determining gases in steel has confirmed the conclusions reported last year, but before publishing results some additional work will be done.

Supplementary work was done upon the Ledebur method for determining oxygen in steel and a paper on the subject is about ready for publication.

The work referred to a year ago on the oxygen content of steels deoxidized in various ways was continued. The various methods of deoxidation used, namely, by ferromanganese, ferrosilicon, aluminum and titanium, have yielded steels with nearly identical oxygen contents as determined by the Ledebur method.

The work on the Ledebur method made necessary an investigation of certain questions connected with the equilibrium between iron oxide, carbon, and hydrogen. It was found that carbon alone (as iron carbide in this case) reduces ferrous oxide at 800° to 900° C., with formation of carbon monoxide and dioxide; as soon as hydrogen

is introduced there is a partition of the reducing action between the hydrogen and the carbide and the proportions of the reduction products (carbon monoxide, carbon dioxide, and water vapor) formed vary with the rate of passage of the hydrogen. With very low rates not more than 20 per cent of the iron oxide is reduced by that gas; a rate of not less than four liters an hours is necessary to effect a 90 per cent reduction by hydrogen alone. This investigation showed also that the rate of hydrogen passage in the Ledebur method should not be less than 4 liters per hour.

Carbon monoxide is an important constituent of the gases extracted from steel when this alloy is melted in vacuo. Certain hydrocarbons, produced by secondary reactions, are also present in the gases. Consequently, in order to determine carbon monoxide in such mixtures, it is desirable to find a combustion method which will burn the carbon monoxide without affecting the hydrocarbons. By the use of copper oxide at 250° C. as an oxidizing agent it was shown that fractional combustion of carbon monoxide is successfully effected provided unsaturated hydrocarbons are absent. It is believed that suitable absorbents for these have been found. A special form of electric furnace for heating several copper-oxide reaction tubes in series was designed and used for this work.

GAS CHEMISTRY.

(Methods of preparation, purification, analysis, and testing of gases, including fuel and illuminating gas, and special gases such as hydrogen, oxygen, nitrogen, argon, etc.)

Balloon Fabrics.

The work on balloon fabrics has made very satisfactory progress during the past year. After a complete survey of the field a program of work was outlined. This was carried out under the auspices of the Balloon Fabric Committee; the result has been a uniform development of the field. The results accomplished during the past year may be briefly summarized as follows:

The methods of examination and testing of fabrics have been investigated and standardized. A method for the determination of the permeability of balloon fabrics to hydrogen by use of the gas interferometer has been developed and adopted as our standard method. Other methods have been tested and found inferior. Two new methods are now being developed and will be used in conjunction with our standard method as the circumstances dictate. One method depends on the measurement of hydrogen by virtue of its high thermal conductivity. The other method determines the hydrogen volumetrically by an ingenious system.

In connection with this line of work a study of the permeability of rubber to different gases is being made. There is very little information available on this subject, and we have frequent calls for such information in connection with the employment of rubber for holding different gases.

The determination of the durability of fabrics has been studied in detail, with the result that it has probably become one of the most important parts of the Bureau's work. An investigation of the fabrics being used in Navy dirigibles enabled us to show the Navy that the fabrics in at least 9 of their 16 dirigibles then under construction were very poor from the standpoint of their lasting qualities. Only 2 or 3 of these dirigibles were accepted before our results

were reported and service tests confirmed our laboratory tests. We not only effected a considerable saving to the Navy in time and money but stimulated the research activities of the companies responsible for the fabrics to such an extent that a wonderful improvement in quality was obtained in a few months.

In the search for a rapid, reproducible exposure test, a thorough study has been made of the use of ultra-violet light, heating in ovens, exposure to light from tungsten lamps, etc., but no satisfactory substitute for exposure to the weather has been found.

During the winter an extensive series of exposure tests was conducted at Pensacola, Fla., with the cooperation of the Navy Department. The Goodyear Tire & Rubber Co. rendered valuable assistance in these tests by preparing without cost to the Bureau a great number of experimental fabrics at a cost of several thousand dollars. The United States Rubber Co. also prepared a series of fabrics for these tests. The results obtained were very useful to the Army and Navy.

The effect of exposure under tension is now being studied in order to throw light, if possible, on the deterioration of fabrics in dirigibles.

The effect of radiation on balloon fabrics is important from two standpoints: First, the rapid changes in balloon temperature produced by sunshine, and, second, its effect on the lasting qualities of the fabric. A study of these points is rapidly nearing completion. The effect of various coatings and pigments in protecting the rubber is a part of this problem.

The effect of impurities in the hydrogen upon the fabric and the balloon fittings has been reported in a preliminary memorandum. Further work on the subject is still in progress.

A new method of study which is being developed may be mentioned; this is the microscopic examination of thin sections of fabric. It is hoped that the cause of failure of certain fabrics may be determined visually in this manner.

During the year over 1,500 permeability determinations were made. Exposure tests were completed on over 175 fabrics. Sixty new fabrics are now undergoing exposure at Washington.

Much work was done on balloon fabrics, both in analyzing them and in studying the changes undergone in storage and when exposed to weather conditions at Washington and Pensacola.

Balloon-Gas Investigations.

The question of the best methods of preparing hydrogen from ferrosilicon and sodium hydroxide in solution was referred to this laboratory by the National Research Council and made the subject of an extended laboratory investigation, as a result of which we were able to explain all the phenomena connected with the reaction and to determine with certainty the effect of each possible variation in methods of generating the gas. Our report of November 5 covering the laboratory work also included recommendations in the form of specific directions for the purchase of material and the operation of the gas generators. These recommendations are the basis of the present practice of both the Army and Navy. The most important single result of our work was to demonstrate the possibility of greatly reducing the amount of sodium hydroxide used in the process with attendant advantages in plant operation as well as economy. The

saving to the Navy alone from these changes was at one time computed to be $700 per day.

An investigation was made upon the effect of sodium carbonate in the sodium hydroxide used in generating hydrogen and the results were employed in preparing specifications for the purchase of sodium hydroxide for military and naval use.

Experiments were also made to determine the feasibility of recovering sodium hydroxide from the sludge from the hydrogen generator by precipitating out calcium silicate with lime. Other experiments were made to determine whether sodium carbonate and lime could be used economically in place of sodium hydroxide in the ferrosilicon method. Both these modified processes were shown to be impracticable.

A study of the literature relating to balloon gases was made at the request of the Navy Department and an extensive bibliography on one phase of the subject prepared for their use.

Methods have been developed and apparatus constructed for the experimental study of the inflammable limits and the propagation of flames in mixtures of balloon gases and air.

A gas density apparatus for determining the purity of hydrogen for aeronautical purposes has been designed for the use of the Navy. The bureau has had constructed and supplied to the Navy 25 of these apparatus and 10 to the Army.

A short report on the effect of moisture on the lifting power of balloons was also prepared at the request of the Navy Department.

Gas Analysis Investigations.

During the year the work upon combustible gas detectors was completed. One form of detector was adopted by the Navy Department for use in submarines in competition with the instruments submitted by a number of other laboratories. After some months of service, trouble developed with some of the instruments, partly on account of excessive vibration of the submarines, which had not been anticipated, and partly because the recommendations of this laboratory were not followed in practice. The wiring, adjustment, and calibration of the instruments was then taken over by this laboratory, and means for testing and eliminating the effects of vibration were devised. More than 100 instruments, 60 of which were wired and calibrated in this laboratory, are now in use, and we have just been requested to prepare 500 more. These instruments probably do not cost more than $30 apiece and replace an instrument costing $500 which had been tentatively accepted by the Navy Department.

A preliminary study has been made of a number of methods for the quantitative determination of the composition of 3-component gas mixtures which do not permit easy chemical separation. This work was requested by the Navy Department; but some of the results may have wide application in other fields.

A laboratory study of one type of balloon leak detector of foreign manufacture was made at the request of the Signal Corps and recommendations were given for the construction of similar instruments in this country. We have also examined, tested, and reported upon not less than 9 other types of gas analysis apparatus for various purposes.

After several unsuccessful efforts along different lines a satisfactory continuous indicator for the percentage of oxygen in the air has been devised and constructed in a crude form. The completion of a compact assembled apparatus to be used as a model is a task for the immediate future.

Routine analyses of the exhaust gases from the aeroplane engines under test at the bureau have been made regularly for the past two months. An apparatus for securing instantaneous readings of the combustible gases in the exhaust is under construction.

Several improvements in apparatus and methods for volumetric gas analysis have been made and are in constant use.

A new form of analytical apparatus depending upon the heat conductivity of gases has been devised and tried out in a preliminary way with gratifying results.

The problem of the continuous analysis of the gases in one of the nitrate plants has been considered and a tentative method for complete analytical control of the plant has been worked out. The experimental work on this problem is just beginning. The heat conductivity method mentioned in the preceding paragraph is to be used for much of this work and it is believed that there will be many other important applications for this method.

Miscellaneous Gas Problems.

A great variety of minor problems and questions are constantly coming to the gas laboratory, principally from the War and Navy Departments. The two most important of these miscellaneous problems were the writing of a large part of the Hydrogen Manual for the Navy and the testing of an oxygen supply apparatus for aviators to determine its suitability for supplying more than one person. The latter problem consumed considerable time only because it was necessary to devise entirely new methods for the study.

REAGENTS AND APPARATUS.

(Study of methods of testing reagents and apparatus to be used in chemical analysis, including study of chemical glassware, porcelain, platinum, and platinum substitutes.)

Chemical Reagents.

Work was taken up in cooperation with the American Chemical Society and manufacturers with a view to improving the quality of so-called "analyzed reagents" by a systematic study of the methods of analysis in general use. Owing to the limited force and the present abnormal conditions, not much progress has been made. A representative of the Bureau visited and conferred with a number of manufacturers, and reagents received for the Bureau laboratories have been tested and the makers advised of the discrepancies between the statements on the printed labels and the actual findings. A report has been submitted to the chairman of the committee of the American Chemical Society. This work is of direct interest to all Government departments and to all other users of reagents, and indirectly affects all users of the products of the industries.

Platinum.

The research upon the chemical and physical properties of the platinum metals has been started, the work of the past year consisting mainly of a study of the literature and of the analytical methods.

From the cooperation of the United States Assay Office at New York the Bureau has obtained loans of platinum, iridium, and palladium for this work. It is purposed to undertake the preparation of pure metals and their alloys for a study of their chemical and physical properties. A large part of the work has thus far consisted in the analysis of platinum gauzes for use as catalysts in the oxidation of ammonia by the Nitrate Division of the Ordnance Bureau of the War Department.

Analyses and tests have been made of samples of platinum foil and sponge for the New York Assay Office.

The New York Assay Office, continuing its cooperation of the past year, has made for the Bureau about 60 crucibles, 22 dishes, and several miscellaneous articles with varying iridium content. These have been tested, and, except for minor mechanical defects in some of the dishes, have proved satisfactory.

Asbestos.

A large number of samples of asbestos from various American localities have been tested as to suitability for the preparation of filters for analytical operations. A supply is now on the market equal in quality to that formerly imported.

OILS, RUBBER, PAPER, TEXTILES, INK, AND GLUE.

(Chemical analysis and investigation of oils, rubber, paper, textiles, ink, and glue, with special reference to meet particular requirements.)

Chemical Work on Rubber.

The Bureau has cooperated with representatives of the Army and with manufacturers in drawing up specifications for rubber tires and for certain types of packings for military purposes. A very large amount of analytical work was done on these materials.

The method for the direct determination of rubber that was referred to in last year's report proved very useful in the analytical work on balloon fabrics.

Following a conference at the Bureau, specifications for two types of gasoline hose were prepared. Rubber is preferable to metal tubing for use on airplanes because it does not break when subjected to long-continued vibrations.

Two types of foreign tanks, designed to be tight to gasoline even when punctured by bullets, were tested. A report covering these tests as well as outlining a method for making such tanks, was submitted to the Signal Corps in 1917. Further work in cooperation with representatives of the Signal Corps was done later.

Chemical Work on Leather.

The chemical testing of leather is a new line of work for the Bureau, but one which it was essential to establish in order to get the most out of certain investigations relating to the physical testing. Three chemists are now necessary to carry on the work for the Army and a fourth is engaged in cooperative work with the National Tanners' Association, as well as in studying waterproofing and preservative compounds. Practical tests of shoes made of leather tanned and finished in different ways are in progress at one of the Army camps.

Owing to the cooperation of a Philadelphia tanner, it became possible to obtain specially tanned and finished bends for a com-

parative study of the effect of different methods of treatment upon the durability of leather. This work is still in progress.

Chemical Work on Writing and Other Inks.

During the year an unusually large number of inks of all kinds were tested. Some confidential work was done for the Navy Department, while more and more testing is being done for the War Department. An ink made at this Bureau for self-recording instruments used by the Weather Bureau proved to be as satisfactory as the French ink that was used previously.

Chemical Work on Paste, Glue, and Mucilage.

In addition to the routine testing of paste, some assistance was given to the United States Food Administration in its attempt to conserve wheat flour. To this end several lots of paste made from potatoes, potato flour, corn flour and starch, etc., were prepared and found to be satisfactory for different purposes. Since receiving suggestions from this Bureau the Food Administration has been able to eliminate the use of wheat flour for making paste. Further, by adopting suggestions made by the Metallurgical Division, all the wheat flour that would otherwise have been used in making foundry cores has been saved for food. The Chemical and Electrical Divisions are cooperating in a study of substitutes for wheat flour in making dry batteries. The total saving from all of the above will amount to thousands of barrels of flour in a year.

It is but fair to say that in all its correspondence with paste manufacturers there was observed a willingness to help. From some there were received valuable suggestions or samples which showed what could be done without the use of wheat flour. This occasion is taken to thank those who have given assistance to this Bureau in its efforts to help the Food Administration.

Some work was done on glue with reference to its use in airplane construction, but most of the samples of glue and mucilage tested were not for military use.

Lubricating Oils and Greases.

The Bureau cooperated with the Navy and the Signal Corps in an extensive series of tests of airplane lubricating oils which were made at the Washington Navy Yard.

Much testing of lubricating oils and greases was done for different branches of the Government.

Chemical Work on Textiles and Dyes.

The chemical testing of textiles is a new field of work at the Bureau. A great amount of this was done for the Army. The work included not only the analysis of fabrics, but also tests of the fastness of dyes and on the fireproofing and waterproofing of textiles.

A collection of dyes, chiefly those used for dyeing Army textiles, is being made for an investigation into the best methods for obtaining materials of fast colors.

For the prosecution of certain military work undertaken by the Optical Division of the Bureau a series of pure dyes is being prepared.

Airplane Dopes.

Dope is a name given to certain preparations that are applied to the fabric of airplane wings in order to impart to them certain

essential qualities. The importance of an investigation of these materials was recognized at the Bureau and begun before our entry into the present war. As a result it was possible 7 months ago to draw up very satisfactory specifications, while even 10 months ago the Signal Corps of the Army officially approved 4 dopes which had been tested at the Bureau. As far as possible all phases of the subject were gone into, including not only the testing of dopes under laboratory and weather conditions, but also the production of cellulose acetate and nitrate and their solvents, the use of plastics, fireproofing materials, etc. The military applications of these matters are obvious.

METALS, CEMENT, AND BITUMINOUS MATERIALS.

(Chemical analysis of metals, including iron, steel, nonferrous metals, alloys such as brass, type metal, solders, etc., coated metals such as tin plate, galvanized metals, etc., lime, plaster, cement, concrete, bituminous materials, including tars, asphalt, roofing papers, roofing felt, etc.)

Chemical Work on Metals and Alloys.

In addition to a large amount of routine testing of ferrous metals and alloys some attention has been paid to improving methods of chemical testing of these materials, and much effort put upon systematizing and expediting work.

Protective Coatings of Zinc.

Much attention has been given to the subject of protecting iron and steel by protective coatings, particularly of zinc.

Investigation of the methods of stripping the zinc coating indicates that the method of treatment with hydrochloric acid and antimony chloride is preferable to that with lead acetate, since the metallic lead precipitated is difficult to remove, especially from irregular surfaces. The antimony chloride method requires longer immersion for sherardized products than was originally specified by its author. It was also found that the thickness of practically all of the coatings is variable, and that microscopic measurements do not give reliable figures for the average thickness.

Certain limitations of the salt-spray test have been discovered which affect the usefulness of this test; for instance, the position of the specimen affects the rate of solution of the zinc coating.

It has also been found that a protecting deposit of a basic salt of zinc is frequently formed on corroded plates which prevents rusting of the exposed base.

The coatings on certain specimens of sherardized materials were found to be so brittle as to be readily removable by sharply bending the specimens. The powder removed by this treatment showed a relatively higher zinc and a lower iron content than the solution obtained by stripping with hydrochloric acid and antimony chloride, which shows that this reagent attacks the underlying iron. The time of action of the reagent is different for materials coated in different ways; an electrically-plated specimen was stripped in from 5 to 15 seconds, dipped specimens are usually stripped in less than 30 seconds, while sherardized coatings require usually more than 60 seconds.

An effort is being made to determine the specific gravity of the zinc coating produced by the various processes so as to permit of

calculating the thickness from the weight obtained by the stripping method.

In order to obtain more definite information regarding the character of the coating produced by the various methods a number of specimens of sheet steel, made from low carbon Bessemer steel, were coated by a number of firms using different processes. These were afterwards exposed to the salt-spray and stripping tests and examined metallographically. Very little relation was found to exist between the thickness of coating as determined by stripping and resistance to the salt-spray test. Hence, an effort has been made to devise a test which can be applied to relatively large samples and which will detect thin spots. The most promising method depends on the use of a solution of sulphuric acid (15 to 20 per cent strength) containing sodium bichromate, which will be further tried out.

Cement, Concrete, etc.

The routine chemical testing of cements, limes, and plasters shows an increase from 1,200 samples for 1916–17 to 5,600 samples for 1917–18.

Special tests and reports of most diverse character were made, some of which are enumerated below.

The Panama Canal Commission was advised regarding the preparation of better specifications for silica sand for steel castings, after a visit had been made to the Washington Navy Yard to observe the practice there followed in the use of that material.

A large number of tests were made in cooperation with Division VII–2 on soils, waters, and concretes, with the object of shedding light on the causes of disintegration of reinforced concrete.

Analyses were made of water, soils, and sands for the Reclamation Service to determine the presence of substances which might be responsible for the slow type of disintegration occurring in constructions of the Crow irrigation projects. The results indicated that the materials used in construction were not the cause of the trouble.

Seven samples of soil from Camp Raritan, N. J., were examined for the presence of any constituents likely to stimulate corrosion of galvanized banding used in the construction of wooden piping.

Analyses of concrete and laitance from a dry dock at Norfolk, Va., showed that the cause of the formation of laitance when concrete is poured was due primarily to the use of an excess of water, with clay in the gravel and the use of waterproofing compounds as contributing factors.

For the Bureau of Mines tests were made of different mixtures of cement, lime, kieselguhr, etc., to be used in gas masks.

For the Department of Concrete Ship Construction analyses and tests were made of samples of sands, slags, diatomaceous earths, prepared clay aggregates, and shales, with the object of producing a light, strong concrete. For the same department tests are being made to determine the value of fluosilicate coatings.

A considerable number of floor hardeners have been analyzed and classified, with the idea in view of carrying out test on the wearing qualities and values of these materials.

At the request of the Constructing Quartermaster General an inspection was made of a car of cement to determine the cause of injury to the eyes and hands of those who handled the sacks of cement in this car. Final results have not yet been obtained.

Bituminous Materials.

The work on bituminous materials has increased very materially during the past year, in spite of the fact that samples from the Supervising Architect have been fewer than in the past. This is due to the military needs resulting from the war.

A number of improvements in methods of test have been made, and this laboratory has collaborated with the American Society for Testing Materials in a series of comparative tests of solubility of asphalts in various petroleum distillates and different grades of ethyl ether. This was necessary as very little work of an accurate nature has been done on this type of materials, and until the last few years virtually no work of standardization of methods has been accomplished. The work on bituminous materials in many of its phases is more or less intangible and many questions remain to be decided. Considering the kind of work and its status of even 5 years ago, it is believed the Bureau is making its influence felt in this field.

In the report for the year ending June 30, 1917, it was noted that the Quartermaster General's Office had requested certain cooperation in passing on prepared roofing purchased for cantonments. A working agreement between the Quartemaster Corps and the manufacturers through the Prepared Roofing and Shingle Manufacturers Association had been arranged, and much of this roofing was furnished under this agreement without test. This arrangement was ineffective and at the present time the Bureau is cooperating closely with the Cantonment Division on prepared roofing. This division still has great need for roofing on new buildings being put up under its supervision, and in the maintenance and repair of roofs laid in the past. The Bureau is consulted almost daily relative to some matters connected with these problems.

It may be mentioned in this connection that representatives of the Bureau and of the Maintenance and Repair Division of the Cantonment Division made an inspection of the roofs at Camp Meade. Requisitions for new roofs to replace the old had been requested from most of the Army camps which aggregated hundreds of thousands of dollars. It was found that the trouble was not due to the quality of the roofing in the case of Camp Meade and that a few hundred dollars for materials and repairs would accomplish the results desired. Investigation is showing the same condition to be true for most of the other camps. The Government has thus been saved many hundred thousands of dollars.

It was suggested in last year's report that this enormous use of prepared roofing on cantonments offered a wonderful opportunity for study of this material in service, and it was further suggested that in a year or so a representative of this Bureau be sent on a tour of inspection to these camps. The time is not yet come, but it is hoped that this opportunity will not be lost when the roofs shall have weathered sufficiently to make it worth while.

The Bureau has been frequently requested to prepare or review specifications for prepared roofing for the Engineer Depot and has tested samples representing hundreds of thousands of squares of material now shipped abroad. Much more of this remains to be purchased and tested.

At the present time the Bureau is working with several branches of the Army and other Government branches on the one hand, and the prepared roofing manufacturers on the other, in the development of uniform specifications for 1, 2, and 3 ply prepared roofings. This work is made more difficult by the present market conditions and the difficulty of obtaining certain raw products, but progress is being made.

In the fall of 1917 the Shipping Board asked the Bureau for specifications for bituminous enamels for the protection of certain inaccessible parts of the inside of steel ships. A provisional specification was hurriedly drawn up from data then on hand, and a more thorough study of these materials was undertaken in order to permit of drawing up better specifications for them. This work had scarcely started when the Philadelphia Navy Yard learned of it, and one of their men visited the Bureau. Arrangements were made for cooperation, and a representative of the Navy Yard was sent to the Bureau to study the problem there for a short time. This work was completed and specifications were sent to the Shipping Board and the Philadelphia Navy Yard.

The Ordnance Department of the Army has asked for aid in the development of bituminous paints for the interior of shrapnel shells. Some paints were made for practical test and specifications suggested.

In cooperation with the American Society for Testing Materials, the chemistry division is studying the penetration needle used for the hardness test on asphalts. A new needle of standard dimensions has been devised and several laboratories are to make comparisons of these with the old needles on a wide range of materials.

Marine Glues.

The Bureau of Construction and Repair of the Navy Yard and the Naval Aircraft Factory at Philadelphia requested of the Bureau information relative to marine glues for use in pontoon construction for hydroaeroplanes, and advised that the marine glue used most by them was an article of foreign source and could not now be had. It may be said that marine glues are not glue, but waterproof cements. An extended study of materials on the market was made and a report rendered to the above-named branches of the military service. Work is continuing on these materials, as new ones are continually being submitted to the Bureau for test.

Coke-Oven Process.

The Chemistry Division detailed members of its staff to assist in a test of a new type of coke oven at Canal Dover, Ohio, and is continuing to check the scrubber efficiency, to test the by-products obtained from this oven, and to make numerous other chemical determinations that were found to be necessary. Plans are being made for investigational work on the light oil and its derivatives—benzol, toluol, and solvent naphtha—that accrue from the operation of this oven.

Protective Coatings for Concrete Ships.

The Concrete Division of the United States Shipping Board placed before the Bureau the problem of developing satisfactory coatings for inside and outside surfaces of concrete ships, both cargo ships of the usual type and oil tankers. This means the development

of oil and waterproof materials of such a nature that they are procurable in sufficient quantities. A representative of the Shipping Board is cooperating at the Bureau in this work.

PAINT, VARNISH, AND SOAP.

(Chemical analysis, testing, and exposure tests of paint and varnish; chemical analysis and specifications for soap.)

Paint and Varnish Specifications.

The Chemistry Division has done a great deal of work in preparing and assisting in preparing specifications for a wide variety of paints and varnishes for various purposes, as follows:

For the United States Shipping Board: Inside white paint, outside slate-color paint, boot topping paint, copper bottom paint and varnish for wooden ships, anticorrosive bottom paint, antifouling bottom paint, hand-mixed red lead paint, ready-mixed red lead paint, bituminous solutions and bituminous enamels.

For the Navy Department: Enamels for airplanes.

For the War Department: "Paint specifications" (this in cooperation with the War Service Committee of the Paint Industry), air-drying and baking enamels for airplanes, shellac-rosin varnish for coating the interior of shells, shellac or garnet lac, and helmet paint.

A specification for airplane spar varnish prepared by the Bureau a year or more ago for the Signal Service of the War Department has been tested by both laboratory and exposure tests. The original specification has met with very general approval by practically every other consuming agency of the Government—International Aircraft Board, Bureau of Construction and Repair of the Navy, United States Shipping Board, several branches of the War Department, and the United States Railroad Administration. The specifications will secure satisfactory material at a low cost, and many manufacturers are now making varnish to comply with it.

Reports to the United States Railroad Administration gave summaries of the Bureau's work on linseed oil substitutes, for some of which extravagant claims are made. Most of them are thin-bodied varnishes with from 60 to 75 per cent of volatile matter. They may be successfully used in certain kinds of paint, but in considering their value as compared with linseed oil, it should be remembered that the non-volatile portion (25 to 50 per cent) should cost no more than raw linseed oil.

Fire-Retarding Paints.

Following a request from the Bureau of Yards and Docks, Navy Department, the subject of fire-retarding paints was taken under study and reported upon in November. Subsequent work tends only to confirm the conclusions of that report, which, briefly summarized, are as follows:

While practically all paint coatings have some fire-retarding action, none of the materials examined afford very great protection. All the samples tested were materially damaged by application of a flame for a few seconds. Both sodium silicate and whitewash rank relatively high. These have the advantage of cheapness and can both be used on the same surface. It is believed that, for interior wood surfaces, the application of sodium silicate solution followed by whitewash may be more efficacious than either one used alone.

However, no treatment of wood after erection can be expected to serve as an effective fire prevention, and the use of such materials should not be taken as an excuse for omitting any precautions tending to avert danger of fire starting or for providing ample facilities for stopping any fire as soon as it starts. Wood construction, no matter how the wood is treated, either before or after erection, involves serious fire risk. It is recommended that claims as to fire-retarding properties of paints be disregarded entirely, since practically all paints have some slight value in this respect and the difference between the best and the poorest is practically negligible.

Removing Metal Fouling from Rifle Barrels.

At the request of the Chief of Ordnance, War Department, a rather extended investigation was made of methods of removing cupro-nickel fouling from rifle barrels. What is believed to be a satisfactory preparation for ready use in the field was finally recommended.

ANALYTICAL METHODS AND STANDARD SAMPLES.

(General methods of chemical analysis, with special reference to methods of standardization; preparation and analysis of standard samples of iron and steel alloys, ores, chemicals, etc.)

Standard Analyzed Samples.

Another very great increase is shown in the demand for the Bureau's standard samples. A good part of this increase was occasioned by the general use of the samples by the Government and by private industries engaged in the manufacture of war material. The number of samples called for during the fiscal year 1918 was 4,836, as against 3,536 in 1917, 2,697 in 1916, and 1,826 in 1915. The distribution was as follows: Iron and steels, 3,674; brass, 80; ores, 357; sodium oxalate, 256; naphthalene, 85; benzoic acid, 44; sucrose, 69; dextrose, 13; metals for melting points, 221; cement for testing sieves, 37.

Three irons, 9 steels, and 2 ores are in process of preparation to replace exhausted stock. A considerable addition to the list of standard samples is now contemplated.

The granting by the present Congress of an appropriation of $4,000 has served to place upon a more stable basis our work on standard samples, but the needs of the situation call for its increase to $10,000.

It is of interest to know that private enterprise in England has made a beginning of providing standard samples for Great Britain. The preparation of the samples and the form of certificate issued are modeled with due recognition after the practice of this Bureau.

Determination of Tungsten and Molybdenum in Ores.

In cooperation with prominent analytical chemists in works, analytical firms and universities, the Bureau has carried on an investigation dealing with the methods of analysis for tungsten and molybdenum ores. As a result of this investigation tentative methods of analysis have been proposed and limited analyzed samples of several ores are available for special use. This work has now been extended to include metallurgical products of tungsten and molybdenum all of which are of much importance for military as well as nonmilitary uses.

6. ENGINEERING RESEARCH AND TESTING.

[Operative efficiency of mechanical appliances, accuracy of engineering instruments, conditions affecting their effective use, e. g., structure and design as related to durability and efficiency; methods of standardization and tests, standards of performance and fundamental researches on the scientific principles involved in speedometers, pressure gauges, water-current meters, anemometers, tachometers, gasoline and other motors, propellers, and other airplane parts and materials, etc.]

Theory of Measuring Instruments.

An exhaustive study has been made of the causes which produce variations apart from the so-called errors of calibration, in the readings of engineering and scientific instruments. The differences from exact reading, commonly known as calibration errors, are not seriously detrimental in the use of instruments, since they can be corrected by simple calculation; another class of errors which may be termed "variance" is disclosed in inconsistencies or deviations of the instrument reading when successive, identical values of the quantity being measured are applied. Such variations from constancy of reading at a given repeated value of the quantity undergoing measurement are not normally allowed for in the calibration of an instrument and means were not hitherto available for general correction of observations for such errors. A detailed discussion of the causes and results of the variance type of errors has been developed by a member of the staff and a paper is in press covering the subject, which is one of great interest to designers and technical users of measuring instruments of many and diverse sorts. The results obtained promise to be of such importance and of such direct application to many of the types of instruments employed in military uses that the continuation of the work will be provided for as actively as the requirements of other projects permit.

Routine Tests of Instruments and Devices.

Calibrations were made of 218 current meters, 60 high-pressure gauges, 66 other pressure gauges, 23 paper testers, 3 anemometers, and 6 water meters. Miscellaneous tests of instruments and devices, including safety valves, condenser tubes, speedometers, gauge glasses, indicator springs, etc., numbered 84.

Tests were made also of powder containers, samples of cast-iron shells, high-pressure flexible metallic tubing, tachometer shafts, odometers, and the like for the various divisions of the Army.

MISCELLANEOUS MILITARY TESTS OF DEVICES AND EQUIPMENT.

Numerous tests of this character were made, including tests of powder containers, samples of cast-iron shells, high-pressure flexible metallic tubing, tachometer shafts, odometers, and the like, for the various divisions of the Army.

MECHANICAL APPLIANCES.

(Investigation and calibration of special mechanical appliances; development of methods and apparatus for standardizing the performance of such appliances; investigation of the operative efficiency of mechanical appliances, such as fire extinguishers, radiator traps, vacuum cleaners, and the like.)

Fire-Extinguisher Investigations and Tests.

The investigation of hand chemical fire extinguishers for the Steamboat Inspection Service has been continued. Tests are being

made and reports submitted to the Board of Supervising Inspections of Steam Vessels of such extinguishers as are being submitted to that board for inclusion in its list of extinguishers approved for use in vessels under its jurisdiction. The number of extinguishers tested during the year was 41, including those submitted for the first time and those previously rejected and again submitted after redesign.

As a result of these investigations a great mass of test data has been accumulated which proved to be of the most vital value to the Government in the present emergency. When it was found necessary to purchase several hundred thousand extinguishers of the carbon tetrachloride type for airplane, motor truck, and similar service, test data were already available relative to most of the machines of this character on the market and these data have been supplied to the fullest extent for the information of the various offices of the Army and Navy interested in the purchase of these devices.

At the request of the Bureau of Construction and Repair, a comparative test of a number of designs of tetrachloride extinguishers selected by that bureau has been undertaken to establish an approved list for the purchase of such devices.

A series of fire tests was made of extinguishers of the so-called dry-powder type, which demonstrated their comparative inefficiency as a first aid fire appliance.

Tests of Airplane Equipment.

To assist the Signal Corps in securing suitable equipment numerous tests were made for the Army of high-pressure oxygen tanks and valves.

Comparative Test of Roof Ventilators.

At the request of the Construction Division of the Army tests were undertaken at the end of the present fiscal year to determine the relative efficiency of a large number of roof ventilators to be purchased by that division for use on Army cantonment and hospital buildings. A report of the results of this work will shortly be made.

Thermostatic Valves for Vacuum Heating Systems.

The investigation of thermostatic radiator valves for vacuum heating systems for the office of the Supervising Architect of the Treasury Department has been continued, to include the new devices of this character submitted to that office in connection with buildings under its control. The efficient and economical operation of a vacuum system is principally dependent on the successful operation of these valves, one of which is connected to each radiator outlet. Tests are made under working conditions to determine if these devices are successful in keeping the radiator up to the temperature of the steam supplied, by the continuous removal of air and water, without permitting the wasting of uncondensed steam to the return line.

Performance and economy test data have been obtained on all the leading brands of such valves. The data obtained have been furnished the Construction Division of the Army for use in the selection of the best type of equipment for the new cantonment, hospital, and office buildings which have been and are being constructed.

ENGINEERING INSTRUMENTS.

(Investigation and calibration of engineering instruments; testing of water-current meters, water meters, high and low pressure gauges, speedometers, anemometers, and tachometers; researches on problems affecting the precision of operation of such instruments, including standards of performance.)

Water-Current Meter-Rating Station.

One of the most important engineering services rendered by the Bureau is the furnishing of accurate calibration of current meters. These instruments are used by civil hydraulic engineers in the measurement of the velocity of flowing water in rivers, irrigation canals, and other open channels, to secure data for the computation of the quantity of water discharged through such channels in a given time, such data being essential in the development of the water resources of the country in power projects, irrigation, flood prevention, and similar projects. To secure accuracy in these measurements, the instruments must be carefully calibrated from time to time. A body of still water must be available for this purpose, together with equipment for towing the instrument through the water at different uniform speeds and for accurately recording the observations.

Adequate installations of this character are costly and are necessarily confined almost entirely to Government stations and large university laboratories, and the latter are not always available for this purpose. In the new rating station designed and constructed by the Bureau especially for this work, exceptional facilities are afforded for the calibration and study of these instruments. The entire flume is housed over and the station is in continuous operation throughout the year. While a majority of the ratings made are for the different engineering bureaus of the Government, this service is also performed for engineers in private practice, a rating curve and table being furnished for a nominal fee.

During the fiscal year 218 current-meter calibrations were made. A series of tests were made to determine the characteristics of a new type of screw-operated current-meter recently developed by an instrument manufacturer. Two current meter ratings were made for the Colonial Department of the Government of the Netherlands.

Current-Meter Investigations.

While the routine calibration of current meters has been continued without interruption, the investigations having for their object the study of problems relating to their characteristics and use have necessarily been suspended during the period of the war in favor of work of a military nature. One investigation, however, made during the previous fiscal year for the United States Geological Survey to determine the variation from the normal meter rating caused by the use of various arrangements of standard weights suspended with the meter on a cable was extended to include certain new equipment recently adopted. When velocity measurements in deep stream are made, such accessories are employed to maintain an approximately vertical alignment of the cable. The series of conversion factors has now been completed, permitting conversion of the standard rating table and application to all arrangements of meter and weights ordinarily used in the field. This renders unnecessary a separate calibration of the meter in each case.

A circular has been issued by the Geological Survey to its field engineers tabulating these data for their use.

High-Pressure Gauges.

During the past fiscal year calibrations were made of 60 gauges intended for the measurement of pressures ranging from 1,000 to 30,000 pounds per square inch. Included in this number are the instruments tested for the Government inspectors of the Ordnance Department for use in the testing of munitions, and for the manufacture of munitions and of gauges. On several occasions calibrated instruments have been furnished to offices in the War Department for the purpose of special tests.

High-Pressure Oxygen Gauges.

For a branch of the Army tests were made on different makes of small gauges for use on high-pressure oxygen apparatus. This work included a study of instruments developed to meet the peculiar conditions encountered in this service, for the purpose of formulating specifications as well as acceptance tests of production samples.

AERONAUTIC INSTRUMENTS.

(Investigation and testing of all types of aircraft instruments, including altitude-measuring instruments, engine speed and air speed indicators, airplane pressure gauges, inclinometers, gasoline depth gauges, mercurial barometers, weather and surveying aneroids, sphygmomanometers, oxygen control apparatus, bomb sights, and rate of climb indicators; development of methods of testing, improvement of design of such instruments, fuudamental researches on underlying principles of such instruments, study of the operation in actual service, provision of the numerical data required in their use.)

After the war began, the general scope of the Bureau's work on airplane instruments was expanded to include practically all types of aviation instruments. Investigations were begun in this and other sections of the Bureau of practically every type under simulated service conditions, and with accelerated tests under exaggerated conditons. Such instruments as used in the modern airplane include the altimeter for indicating height above ground, compass for indicating north, inclinometer for indicating the angle of the plane with respect to the horizon, airspeed indicators for relative speed of plane and the air, tachometers for showing revolutions of engine shaft, special nonfluid thermometers, pressure gauges for the engine, gasoline level indicators, timepieces, oxygen control apparatus, statiscope to show whether the aircraft is rising or descending, range finders, angle-of-attack indicators, and the like. The prompt, reliable readings of these instruments are vital to successful aircraft control upon which depends the accurate control of gunfire, the mapping of enemy positions and movements, as well as the efficiency of action of bombing and fighting planes.

The Bureau has collected examples of the typical French, English, and American aviation instruments, as well as of German instruments captured by the French. All available data regarding the construction and use of the various instruments has been placed at the disposal of manufacturers and interested officers of the War and Navy Departments.

An important part of the work of the Aeronautic Instrument Section has been the instruction of inspectors in the Bureau of Aircraft Production in the testing of the instruments which they are to inspect at the factories for Army and Navy use.

A series of technical circulars has been prepared discussing the principles involved in the various aeronautic instruments and the methods of testing employed at this Bureau. These circulars are for the instruction of the experts engaged in aviation work. Large num-

bers of these circulars are called for by the technical divisions of the Army and the Navy.

A series of lectures was conducted for a group of naval aviation officers on the principles of operation and methods of testing the different aeronautic instruments. Plans are under way to complete this course, with extensions to other groups of naval and Army officers.

Oxygen Control Apparatus.

The oxygen control apparatus is of special interest in view of its vital relation to the physical condition of the aviator at high altitudes. At higher levels the aviator must have artificial sources of oxygen, and these must be of known and assured reliability. The apparatus delivers oxygen in amounts which are regulated by an aneroid control valve, so that the amount of oxygen delivered is correct for each altitude. The performance of the entire device is being investigated in the aviation instrument laboratories of the Bureau. The Bureau has studied the effect of the variations in temperature upon the accuracy of the action of these instruments, and has also made suggestions looking to the removal of defects and improvement of operation.

Statoscope Design.

A serious defect in the existing design of the statoscope was discovered. The statoscope is used to indicate with extreme sensitiveness whether a balloon or aircraft is ascending or descending. The Bureau's knowledge of the technical points involved in airspeed indicator design enabled it greatly to assist the American manufacturers in improving the quality and quantity production of such instruments.

Barographs.

An interesting and important development devised at the Bureau extends the range of barographs so that they will operate at higher altitudes than the instruments were constructed to encounter. The Bureau has also devised an electrical spark method of recording graphically the changes in pressure which indicate the altitude of aircraft.

The Bureau has computed new pressure altitude tables covering all heights up to 35,000 feet. These have been duplicated and furnished to the military officials concerned. The Bureau has also computed tables of temperature corrections to these tables to correct the variations in readings of barometric devices caused by temperature fluctuations. Tables of data such as those mentioned will greatly aid in the accurate location of position in the air with a view to due allowance for altitude in bomb dropping and for other purposes.

Airplane Thermometers.

The Bureau suggested sometime ago to the manufacturers of thermometers the making up of airplane thermometers of the pointer-and-dial type, operated by vapor pressure. Some of these were made up in the factories and submitted to the Bureau of Standards for complete test. The results were gratifying and it was shown that the new instruments possessed marked advantages over those previously manufactured. For high altitudes, the ordinary thermometers would not be usable on account of the freezing of the mercury.

Testing and Investigation of Aeronautic Instruments.

An important aspect of the Bureau's researches on aeronautic instruments has been the provision of laboratory facilities whereby the

conditions at high altitudes could be simulated—for example, the pressure, temperature, and the vibration peculiar to airplanes, in order that the behavior of measuring instruments might be accurately studied under conditions found at any and all altitudes and conditions likely to be encountered in flight.

In testing the aeronautic instruments a special temperature chamber was constructed provided with cooling coil, fan, and heater for controlling the temperature within the inclosure. Aviation instruments are placed in the chamber to determine the error resulting from temperature changes experienced in airplant flight. The apparatus was found perfectly adapted to test thermographs—self-recording thermometers for recording changes in the air temperature during airplane flights. While the data provided by the Bureau cover altitudes beyond those ordinarily used in military operations—in some cases altitudes of 40,000 feet—the rapid progress in aviation makes it desirable to anticipate the possible developments of the near future.

Aeronautic instruments, including a newly designed pressure gauge and valves for high-pressure cylinders, have been tested at very low temperatures. A low temperature comparator was built for tests of oxygen cylinders at low temperatures, high pressures, and with mechanical vibration—to get conditions encountered in high altitude airplane flights.

AERODYNAMICS.

(Measurement of the resistance of the air to the motion of bodies relative to it, including the determination of the magnitude, direction and point of application of the resultant force, and its relation to the relative speed; study of the aerodynamical properties of airplane wing models, stability of model airplanes, efficiency of propellers and wind motors, characteristics of air bombs, and testing of airplane equipment and other apparatus functioning in an airstream.)

Wind Tunnel Investigations.

The construction of the Bureau's new wind tunnel building was undertaken in September, 1917, and completed, including the installation and operation of the wind tunnel, in January, 1918. The room housing the tunnel is 70 feet long, 29 feet wide, and 18 feet high, with a self-supporting roof. The building contains in addition a small shop, a computing room, and a drafting room on the mezzanine floor above these.

The wind tunnel is of the open type, octagonal in cross section, the distance between opposite faces of the octagon being 54 inches. The straight portion of the tunnel is of wood, supported by a structural-iron framework. The entrance and exit cones are constructed of the cotton cloth used for covering airplanes, doped and varnished, and supported on an open steel and wood framework. The wind stream is maintained by a tractor propeller 9 feet in diameter, mounted directly upon the shaft of a 100-horsepower direct-current motor. An air speed of 90 miles per hour is attained with an expenditure of about 85 electrical horsepower.

The tunnel is equipped with two weighing balances, so arranged that either can be used independently of the other, but not, of course, simultaneously. One balance is of very heavy construction, designed to carry heavy models, such as air bombs and engine radiator sections, and is adapted for lift and drift measurements only. The other balance, which is a modification of the National Physical Laboratory type, is designed primarily for the investigation of the characteristics of airfoils and airplane models. The measurement of the moment from which is determined the center of pressure of

the airfoil is made by means of an auxiliary balance connected with the moving member of the main balance in such a manner that it is possible to measure lift, drift, and moment simultaneously.

The wind tunnel, since its completion, has been devoted almost entirely to work of a military nature, including tests of airfoils, models of airplanes and dirigibles; tests and calibration of air-speed indicators of the Pitot, Venturi, and combination Pitot-Venturi types; investigation of propellers for driving the generators used in aeronautic radio signaling, to the end of developing a constant speed propeller; testing bomb-dropping devices and determining the characteristics of aerial bombs in the wind stream; investigating the head resistance of a large number of radiator sections; and other work of a similar character for both the Army and the Navy. In addition, cooperation has been afforded another division of the Bureau in making an extensive investigation for the Quartermaster's Department of the efficiency of various types of ventilators.

The tunnel has also been used in an investigation of wind stresses on power lines and telephone and telegraph wires under conditions in which the wind resistance is increased by a coating of ice on the wire.

Free-Flight Investigations.

The purpose of the work has been to develop the instruments and methods which will make it possible to secure continuous autographic records of the performance of an airplane and its power plant during a free flight of the airplane under the normal operating conditions. The quantities which it is most important to record autographically are: The torque and revolutions per minute of the engine, the thrust of the propeller, the speed of the airplane with reference to the air, and the angle of incidence of the wings and their inclination referred to the true horizon. The measurement of these quantities on a full-sized airplane in free flight would furnish the ultimate test of the theories on which airplanes are designed. It would add greatly to the value of all the laboratory studies of airplanes and their engines which are now being made, by showing what corrections must be made to the direct conclusions from such studies to fit them to the actual conditions under which full-sized airplanes operate.

During the year all 6 of the new autographic instruments desired have been designed. The construction of the torque meter, of the thrust meter, and of the angle of incidence meter have been completed and these instruments are now awaiting laboratory tests and calibration. The airspeed meter is nearly completed.

The instrument for determining the inclination of the wing chord, known as the Bureau of Standards stable zenith, has been subjected to extensive tests, which have demonstrated that it will serve its purpose in the air with a much higher degree of accuracy than any other known instrument. This instrument combines two gyroscopes in a novel manner which secures a great gain in accuracy and in adaptability to various conditions. It is believed that out of the instrument there will be developed in due time a group of new gyroscope instruments adapted to various uses.

All of the above work described in this section has been done in close cooperation with the National Advisory Committee for Aeronautics.

7. STRUCTURAL, MISCELLANEOUS, AND ENGINEERING MATERIALS.

[Investigation of properties, use, fabrication, and design of structural, miscellaneous, and engineering materials; development of specifications covering the use of such materials; improvement of processes of manufacture; improving present and developing new methods of testing; development of testing apparatus.]

METALS.

(Development of airplane design, including structures, and appurtenances and discovery of suitable materials for construction purposes, especially metal construction; investigation of processes for kiln-drying of timber; design and calibration of airplane flight recording instruments; welding research for ship construction; calibration of testing machines and extensometers; standardization of hardness testing with various machines; determination of the physical properties of metals, woods, molded materials, and rope.)

Investigation of Metal Airplane Beams.

Extensive experiments have been made this year on sheet steel and aluminium alloy as a possible substitute for spruce in airplane structure. The resisting moment of the present spruce spar was computed, and possible sections formed of sheet steel and alminum alloy were compared for resisting moments and weights per linear foot. Specimen metal beams were also tested to failure. In these tests aluminum was found to offer the best prospects.

Extensive experimental work was carried on in cooperation with a metal company at College Point, N. Y., who made metal parts from designs furnished by a member of the Bureau staff. This member of the staff spent several months at College Point supervising the work in person. Steel and aluminum alloy were used and it was found that cold-rolled steel beams had only about one-half the strength of wood. Aluminum gave more promising results, and was used for the beams of two sets of Curtiss JN–4B wings, whose ribs, ailerons, and other parts were of steel. Flights totaling about 60 hours were made in an airplane equipped with these wings at McCook Field, Dayton, Ohio, and no deterioration in their structure was found. Sand-loading tests of the flown wings, and of duplicate new wings gave a factor nearly the same as that obtained with a set of Curtiss wood wings.

Heat-treated steel beams were tested under combined bending and axial load to determine their strength. A rough test on beams heat-treated in this manner showed a high modulus of rupture. Judging from these tests the heat-treated steel beams have the same strength as the wood beams.

Other aluminum alloys, one of which contained silver and copper, were tested in tension and bending to determine their suitability as a material for airplane construction. Tests showed that these materials were not as favorable as other materials procurable. All of the data obtained from these experiments have been embodied in the "Report on Steel Construction" for the Advisory Committee for Aeronautics.

Substitutes for Spruce in Airplane Construction.

In an endeavor to find suitable substitutes for spruce in airplane construction, numerous tests were made on the following woods: Cypress, fir, juniper, gum, redwood, tanwood, cuban wood, oak, ash, mahogany, pine, balsa, majagua, tupelo, Spanish cedar, Brazilian

walnut, and California spruce. In general, the tests showed that cypress and Douglas fir offered the best possibilities. Balsa wood proved to be very light, soft, and elastic, but of a lower specific strength than woods now used for airplane construction. Spanish cedar was also found to be satisfactory from the point of weight and uniformity of structure, but low in strength compared with other available woods. On the other hand, tupelo wood was found to be excessive in weight as well as deficient in strength, while Brazilian walnut proved to be rather heavy but of correspondingly high strength. Short-leaf pine from Arkansas was found favorable, while majagua wood proved, under tests, to be unreliable and inconsistent, due apparently to the irregularity of the sap and heartwood. As a rule specimens showing a large percentage of sapwood proved to be the stronger.

Investigation of Mahogany for Airplane Propellers.

Several kinds of mahogany were subjected to expansion tests, after their moisture content had been reduced to zero by oven-drying, to obtain information as to probable distortion or warping of airplane propellers, the present construction of which is largely of that wood. After first reducing the moisture contents of these specimens to zero by oven-drying, they were exposed to air for different lengths of time and the expansion measured. Further tests were made by exposing the specimens to an atmosphere of high humidity. All the species tested were affected about equally by given changes in the moisture content, but the true mahogany absorbed moisture much more slowly than the other varieties.

Investigations of the Effects of Kiln-Drying Spruce.

The investigation started last year to discover the effect of kiln-drying on spruce to be used for airplane manufacture has been continued this year. A member of the department visited several places where kiln or other methods of drying were used. The methods studied involved the drying of cypress and Port Orford cedar as well as Eastern and Western spruce. While all the methods were not equally satisfactory, and it was necessary to compare the cypress and cedar with data collected from air-dried spruce, due to lack of data on air-dried cypress and cedar, the general conclusion was that, with improvements of the process, artificially dried wood would prove just as satisfactory as air-dried.

Airplane Strut Investigation.

This investigation, inaugurated some time ago for the determination of proper strut formulæ for airplane design, was progressed to the completion of tests on struts ranging from 24 to 255 L/R with both square and round ends. The results of the investigation have been prepared for formal publication as one of the contributions of the Bureau of Standards to the work of the National Advisory Committee for Aeronautics. A number of typewritten copies have been made to supply any demands that may be received before the publication is completed.

Aluminum latticed and veneer spruce struts have also been tested and a report made on the former. One of the 30-foot aluminum

girders was tested with a uniform transverse loading and direct axial compression. This girder was also tested supported at one-third points to duplicate service conditions and the ultimate compression load recorded.

Airplane Thrust and Torque Dynamometers.

Much of the time of one member of the division was spent on the detailing of thrust and torque meters for determining engine performance under flight condition. Detail drawings of the torque dynamometer were prepared under the supervision of this division. The completed drawings were sent to the shop and the instrument has been completed, except for minor details.

A thrust dynamometer was calibrated under static and dynamic conditions for the Bureau of Steam Engineering of the Navy Department.

Instrument for Measuring Tension in Airplane Cables.

The "tensiometer," an instrument for measuring of the loads on airplane cables, was designed by a member of this division and made in the division shop. This instrument, after being successfully tried out and calibrated, was submitted to the Navy Department for inspection and was reported on favorably by them.

Shock-Absorbing Wheels for Airplanes.

Tests were made in radial compression and side thrust on two wheels designed to substitute spring rods for radial spokes, and also to put sheet-metal cases in place of pneumatic tires in obtaining the required resiliency. These tests revealed certain defects in design which were corrected by the manufacturer, and tests on the corrected wheels showed them to be about 30 per cent stronger in resisting side thrust. These proved stronger in side thrust and weaker in radial compression, but did not prove as stiff as the wheels with the original hub construction.

Investigation of Magneto Couplings for Airplane Use.

Three magneto couplings were investigated for the Signal Corps to determine their suitability for airplane use. They were tested for mechanical strength and for durability of the flexible rubber connections, and were found to be satisfactory.

Sea-Plane Tail Booms.

Tests were made on 4 hollow spruce tail booms of two different sections and weights but of the same length. The larger sectioned boom was only 20 per cent heavier, but 60 per cent stronger.

Metal Wheels for Motor Trucks.

An investigation as to the suitability of metal wheels for motor trucks was undertaken for the Quartermaster's Department of the Army. These wheels were tested to destruction in radial compression and side thrust. A Government design of composite wheel, also tested, was found to be superior in some respects. Tests were made on two composite cast steel wheels and two pressed steel wheels which differed from the wheels previously tested by having web spokes and a brake drum cast as an integral part of the wheel. Reports on

these tests were sent to the Quartermaster's Department, Ordnance Department, and the Signal Corps.

Tests of Palmetto Wood for Sea-Faring Purposes.

A sample of palmetto wood was tested for water-excluding purposes at the request of the Bureau of Construction and Repair of the Navy Department. Oven-dried specimens were tested for the per cent of water absorbed in a given time, and compression tests were also made. Compressive and shear tests were made on specimens which had not been previously dried. The results obtained showed this wood to be exceedingly weak both in compression and shear.

Investigation on Failure of Steel Plate.

Tests on the steel plate which broke last June, under crane manipulation, at the Homestead Steel Works, have been completed. This investigation was attacked from the standpoint of internal stresses. Besides tensile tests, microscopic and chemical analyses were made, and the whole embodied in a report which was sent to the Bureau of Construction and Repair of the Navy Department.

Investigation of Electrically-Welded Plates.

Arc-welded sheets were tested for the Steamboat-Inspection Service to determine their availability for lifeboat construction. Tension tests showed the arc welds to be 100 per cent efficient. Alternating stress tests showed that the welded section was not injured appreciably during the process of welding.

An investigation of spot-welded top joints proposed for airplane construction was inaugurated to determine the efficiency of the welds. Certain drilled and rectangular tubular sections were also tested in cross bend and tension to determine their relative efficiency for this purpose.

Investigation as to Cause of Failure of Bearing Plates and Rollers.

Two bearing plates and 5 rollers from the thrust bearing of the turbo-generator units of the Gatun hydroelectric station, submitted by the Panama Canal, were investigated for cause of failure. The failure of one of the bearing plates was found to be due to quenching cracks, while the second one failed from abrasion of the surface; the rollers in this instance being harder than the plates. The heat treatment required to produce the necessary hardness and still not develop quenching cracks was ascertained.

Investigation of Floor Stress in the New Arlington Building.

Strain gauge measurements on the reinforced concrete floor slabs of this building were taken for the Treasury Department. All the field work has been completed and the data and conclusions are being prepared for a complete report.

Machine-Tool Investigation.

The investigation inaugurated last year in cooperation with the Research Committee of the American Society of Mechanical Engineers on the cutting action of machine tools was continued this year. A cutting tool of the De Leeuw type was designed and drawn

in detail and the library searched for literature of value in this connection.

Report on Extensometers.

Two well-known types of extensometer were attached to the same specimens in tandem and data for stress strain diagrams were obtained. Comparison of this data showed that the one instrument, although more convenient to use, has not the precision of the other. It can be used to advantage in obtaining the elastic limit and the yield point, but not for precise determinations of the modulus of elasticity where set measurements are necessary.

Adaptability of Scleroscope for Testing Rubber.

An investigation was made as to the adaptability of the scleroscope numeral as an index in determining the physical properties of solid rubber tires. A certain degree of proportionality was found to exist in using this numeral in predicting physical properties. The similarity of this test with the Whiteney rebound test, already established in rubber testing, was pointed out in the report made.

Depth-Measuring Appliance for Brinell Hardness Machine.

An instrument company supplied the Bureau with a depth-measuring attachment to be used with the Brinell hardness testing machine. This instrument is being tried and the relation between depth and diameter measurements for hardness will be worked on with the object of determining a conversion factor.

Brinell Meter Investigation.

An investigation was made of a Brinell meter submitted by the Boston Navy Yard for the purpose of obtaining the Bureau's opinion as to its value. This was accomplished by tests made on standard bars and specimens with the Brinell meter and the regular Brinell machine. The object of the investigation was to determine the relative precision of these instruments, standardize the practice, and to facilitate the tests for hardness in munition plants. Considerable data were gathered as to the comparison of hardness numerals obtained with the Brinell meter and with the Universal Brinell machine. The report on the investigation recommends the Brinell meter, if a variation in Brinell hardness numerals to plus or minus 5 per cent is permissible.

Calibration of Testing Machines.

A number of calibrations (both direct and by comparison) have been made this year by the department. Besides calibrations of the Bureau machines, 9 machines with capacities ranging from 60,000 to 300,000 pounds have been tested by means of the Emery-rating levers. A great many more have been calibrated by means of calibration bars.

Considerable work was done in connection with a comparison test of the 800,000-pound chain tester at the Boston Navy Yard with the large Emery machine at the Bureau. This necessitated the designing of an outfit to obtain a comparison of the tension and compression supports of the large Emery. Certain changes in the design of this apparatus have also been made as to capacity and recording device,

such that the work of calibrating commercial testing machines may be accomplished with it. The machine work for this is under way in our shops. The original design of a hydraulic capsule has been revised to adopt it to calibration of testing machines up to 500,000 pounds capacity. The revision consists mainly of a multiplying system of diaphragms and suitable scale beams for weighing the applied load.

Investigation of Galvanized Wire to Determine Loss of Ductility.

The investigation undertaken last year for a steel and wire mill to determine the reason for loss of ductility in wire due to galvanizing was completed this year. Four types of coated rods—"rust-resisting" black finish, Lohmann lead-coated, Meaker electroplated, and Parker rustproof—were tested for another firm, and 6—copper cyanide, sherardized zinc, cyanide, pickled, shot-blasted, and zinc sulphate—for another. These specimens were heat-treated and then given tension tests.

Investigation for Changes in Design on Specification of Materials Submitted by the War Department.

A number of tests have been made for the Ordnance and Quartermaster Departments and the Signal Corps, with the object of recommending changes in design or for determining specifications. Among these the following tests were the most important:

Electric butt-welds were investigated from a metallurgical, chemical, and physical standpoint and were found to be of a superior character.

Retard and safety springs employed in French detonating fuses and steel and bronze springs from French motor fuses were tested in accordance with French specifications, to determine the specifications for our departments.

An extract of existing specifications on manila rope was compiled to form a basis for new specifications to be submitted to the cordage manufacturers.

A fairly exhaustive report on the physical properties of bakelite, silicon-steel, Swedish iron, phosphor-bronze, German silver, spring steel, and woods was furnished the Electrical Engineering Section of the office of the Chief Signal Officer. The information was requested in connection with construction of insulators, magnet cores, armatures, yokes, contact and tension springs, as well as boxes and cases for field-signaling equipment. Reference to additional literature and recommended practice were also included.

To obtain information upon which to base specifications, many miscellaneous tests were made on bolts and nuts, turnbuckles, steel wire and cables, and sheet steel for gasoline tanks. The last two items comprised over 400 individual tests, which were made in our laboratories, in greater part, by members of the Signal Corps.

Three sets of piston rods for a 12-inch barbette carriage were tested in the large Emery testing machine. In no instance was the proof load sufficient to reach the yield point of the rods.

In addition to the usual tests made every year, a great variety of special tests have been made this year, for different branches of the

War Department. This work comprised tests on steel for naval guns, shovels and hoes, oak keel blocks for ships, transverse girders, a 150-ton floating crane, chrome-vanadium steel, magneto couplings, trench jacks, French airplane material, aluminum girders, veneer struts, piston rods, electric-welded wrought-iron bars, welding refrigeration pipe, Army knives, armor plate, wire cable clamps, loading of shells, wall boards, celluloid, wire rope, lock nuts, brazed joints, gas mask parts, electric-welded steel mesh for concrete reinforcement, mess spoons and forks, fuse parts, copper-covered wire cables, bakelite control pulleys for airplanes, copper-coated wood for airplane propellers, powder containers, vulcanized fiber, eye splices, strap ring bolts, coupons of boiler plate steel, belt fasteners, halter chains, welded steel rings, steam pipe insulators, insulated copper wire, axes, machetes, manganese-steel bars, cutter blades, nickel-steel tubing, specimens of verilite, elastic safety belt, leggings, belt buckles, Duff jacks, Simplex jacks, meter oxygen tanks, sash chain, zinc for battery tinning, ash and hickory trench spade handles, compression grease cups of sheet metal, bakelite insulations, powder containers, buttons for uniforms, etc.

Equipment.

During the year the following equipment has been added: Small Olsen transverse bending machine, capacity 10,000 pounds; constant-temperature electrical oven for determining the moisture content of woods; Erichsen machine for finding drawing properties of different sheet metals; Riehle extensometer; Brinell meter; Olsen impact machine, capacity 400 foot-pounds; Izod impact machine, capacity 120 foot-pounds; Charpy impact machine, capacity 60 kilogrammeters; Olsen testing machine, capacity 50,000 pounds; cross-bend testing machine for testing veneer boards and wall boards; improved Riehle extensometer; Olsen tension and compression machine, capacity 20,000 pounds; wire-testing machine, capacity 2,000 pounds; Upton-Lewis repeated stress machine; 6-rotary repeated stress machines for testing aluminum alloys and wood; Berry strain gauge for tests of concrete buildings; apparatus for calibrating extensometers and strain gauges; speed-reducing mechanism for the recording drum of the Upton-Lewis repeated stress machine; 2 new lathes; 4 cabinets for small instruments and tools.

Investigation of Brick Piers.

The investigation upon brick piers was completed during the past year and the report of results is now in press. This investigation was taken up in cooperation with the National Brick Manufacturers' Association. It includes compression tests of over 50 piers $2\frac{1}{2}$ by $2\frac{1}{2}$ feet in cross-section and 10 feet high, which were constructed of various grades of brick and mortar and with different types of bonding. The bricks were selected from 4 of the representative districts east of the Mississippi, so as to be typical of different manufacturing outputs. The brick were graded as to hardness according to the tentative specifications of the American Society for Testing Materials.

The following are the conclusions drawn from the results of tests. The strength of brick piers depends primarily on the quality of brick and kind of mortar used. Of the mortars used, the cement mortar develops about twice the strength of the lime mortars, or 2,700 and 1,400 pounds per square inch, respectively, for the highest grade of brick. The cement mortar is harder to work, however, and a combination lime and cement mortar which does not appreciably affect the strength of the piers is cheaper, and has much better working qualities. The combination used in the present investigation was 1 part of cement and lime (by volume 65 per cent and 35 per cent respectively) to 3 parts sand. The strength of piers laid in the combination cement and lime mortar was practically the same as those laid in a 1:3 cement mortar, giving twice the strength of those laid in 1:6 lime mortar and about four times the strength of those laid in 1:3 lime mortar. The type of bond as concerns the number of header courses used has little, if any, effect upon the ultimate compressive strength of the piers. The introduction of wire mesh in the horizontal joints adds strength if used in all the joints. This does not apply, however, if used in every third or fourth course only, and may even decrease the strength of the pier. The transverse, rather than compressive strength of the individual brick, is believed to bear the closer relation to the ultimate strength of brick masonry.

Investigation to Determine Bearing Power of Soils.

This investigation was taken up in cooperation with the American Society of Civil Engineers' committees on soils, and has been continued during the past year. The physical properties of different types of earths are determined by laboratory tests and the results compared with measurements made in the field. The field tests have shown that there is in many cases a considerable range of variation in the observed data, even when the tests are conducted under identical conditions, upon soils having the same structures, but at different observation points. These variations have been found to depend upon the relative densities of the earth, the character of the aggregate and binder, moisture content, and other variables. The laboratory tests have been conducted for the purpose of ascertaining the relative influence of the more important factors which control the bearing values of soils in relation to foundations and other engineering structures.

General Summary of Testing.

The following is a summary of the testing done in this division, and represents an increase of 50 per cent over the number of specimens tested during the previous year:

Tests for the Navy Department.

1. Bureau of Construction and Repair	175
2. Bureau of Yards and Docks	24
3. Other branches	49

Tests for the War Department.

1. Ordnance Department	344
2. Quartermaster's Department	113
3. Bureau of Aircraft Production	670
4. Engineering Department	145
5. Surgeon General's Office	10
Tests for the Panama Canal	147
Tests for the Department of Interior	12
Tests for Treasury Department	6

Tests for Department of Commerce.

1. Bureau of Standards	388
2. Other branches	6

Tests for United States Shipping Board.

1. Shipping Board	19
2. Emergency Fleet Corporation	36
Tests for the Post Office Department	1
Tests for National Advisory Committee for Aeronautics	52
Tests for private firms and individuals	793
Total	2,990

Calibration of Testing Machines.

It evidently comes within the work of this section to calibrate testing machines. Recently the materials-testing laboratories at both Worcester Polytechnic Institute and the Massachusetts Institute of Technology have requested very earnestly that some at least of their machines be calibrated by this Bureau.

They find this necessary because they are testing materials for acceptance under Government contracts.

It appears feasible to construct a machine for applying dead weights possibly up to 200,000 pounds. This could then be used to calibrate a tension bar or other apparatus for use in determining the error in any given testing machine.

The design of this machine is now being considered. Apparently its cost would be high, due to the present price of cast iron, which would be used for the weights.

New Equipment.

A large capacity testing machine for transverse tests upon beams and other engineering structures should be provided for the new laboratories in the Engineering Building.

A torsion machine of larger capacity and greater accuracy would also be desirable. It is evident that the equipment at present available for making transverse and torsion tests is much inferior to that provided for other work.

Considerable work has been done upon calibration of hardness apparatus of the Brinell type. It would be advantageous if a dead-weight machine of this type was provided by means of which the hardness of standard bars could be determined. If this work could be done rapidly and accurately at this Bureau, many manufacturers would submit samples of the metals they are using, for standardization.

Two special devices for calibrating extensometers were designed and built. One of these handles all types of extensometers that will go on a standard 0.505 inch diameter round specimen. The other device is for calibration of extensometers of the Berry strain gauge type. Both devices take instruments with any gauge length from 2 to 10 inches. A number of strain gauges and extensometers have been calibrated with these devices.

General Tests of Structural Materials.

A number of tests not classified in the reports of research have also been made for different departments of the Government and various manufacturers. These include 30 tests of manila rope in sizes up to 3 inches diameter, 52-wire rope in sizes up to 1⅝ inches diameter, 4 concrete columns of diameters 12 to 20 inches, 12 bridge rollers, 6 porcelain insulators 12 inches diameter for wireless towers, 7 tests of large chain links, 46 compression and modulus tests of porcelain, and a number of special tests of brick, tile, and steel bars. A number of special tests were made upon projectiles according to Government specifications.

The following tests were conducted for different departments of the Bureau of Standards: Compression tests on approximately 1,200 concrete cylinders 6 inches diameter, 640 tests on 2-inch cubes of cement, 360 tests of 2-inch cylinders of lime composition, 600 cylinders 2 inches diameter of floor cement, and 600 transverse tests of bars of floor cement.

Tests of Tile Walls.

A number of tests have been conducted on walls of tile varying in thickness from 6 inches up to 12 inches, in widths 3 to 6 feet, and 10 and 12 foot heights. The strength of the wall when tested in this manner varies from 200,000 up to 600,000 pounds or more, depending on the thickness of the walls, and the geographical district from which the tile was selected, some clays being superior to others for developing strengths. The tile are laid in some cases with the flues running vertically, which develops the greatest strength. Comparative tests are also being made with the flues laid horizontal. This does not give as great compressive strength, but the walls laid in this manner possess greater lateral stability.

These tests have been continued the present year. A great deal of interest has been manifested in the tests by manufacturers, Building Code Commission, and architects. It is believed the data will ultimately be of great value in devising equitable specifications covering this important material.

CEMENT, CONCRETE, STONE, GRAVEL, AND SAND.

(Investigation and testing of materials for construction purposes; development of new methods of testing; improvement of apparatus for testing; preparation of specifications covering structural materials; development of new uses for cement products; distribution of knowledge as to use of materials; design and fabrication.)

Investigation and Testing of Cement, Concrete, and Stone.

The work of the section during the year has been radically affected by war conditions. Several of the normal continuing investigations have been largely or wholly set aside by the continually increasing amount of emergency and special work, and the end of the year discloses a program almost entirely devoted to war service. Thus no

work has been done in connection with the investigation of the value of integral waterproofing compounds, the durability of concrete in alkali waters, nor upon the further development of the granulametric analyzer and air separator for cement, which were described in the last annual report. On the other hand, the routine inspection and testing of cement for the War and Navy Departments has increased to such an extent that a very considerable expansion in the Bureau's facilities for work of this character has been necessary, and still further expansion will be required in the immediate future. Special problems in the fabrication and adaptability of concrete for specific purposes and tests of a large variety of new or unusual concrete aggregates have occupied the entire time of an enlarged laboratory force. Considerable progress has also been made in the investigation of building stones, but less has been accomplished in this line of work than during the preceding year.

New Branch Laboratories at Denver and San Francisco.

At the beginning of the year the materials testing laboratories of the Reclamation Service at Denver and San Francisco were transferred to the Bureau, and were made immediately available for the work of all Government departments. As a result of the transfer the testing work at these points was increased to such an extent that, while all demands of the Reclamation Service were met, a much larger portion of the work, especially during the latter part of the year, was devoted to military and naval requirements. In the enlargement of the scope of the work at these laboratories it is intended to gradually make them available for broader and more general service, not only to the Government departments but also to the public, particularly for service which can not properly be performed by commercial or private laboratories.

Government Specification for Portland Cement.

The standard specification for Portland cement which became effective January 1, 1917, contained a clause to the effect that on and after July 1, 1918, the Government specification would require an increase in fineness, reducing the permissible residue on the standard No. 200 sieve from 22 per cent to 20 per cent by weight. At a meeting of the Departmental Cement Committee held April 2, 1918, the postponement of this requirement was discussed and eventually recommended in the adoption of the following resolution:

> Moved, that the requirement for fineness of cement in the present specification, as follows: "The United States Government specification requires that on and after July 1, 1918, the residue on the 200-mesh sieve shall not exceed 20 per cent by weight," be changed to take effect six (6) months after the close of the war with Germany instead of July 1, 1918.

This recommendation was subsequently ratified by the Departmental Conference and approved by the heads of the several departments. The change becomes effective July 1, 1918, and all copies of Bureau of Standards Circular No. 33 (United States Government Specification for Portland Cement) issued after June 1, 1918, contain an insert announcing this change in the specification.

To avoid any misunderstanding of the Government's attitude regarding this change, it may be stated that the departmental committee in submitting its resolution expressed its unqualified belief in

the value of the increased fineness required in the specification. Upon representations from the War Industries Board, however, and in recognition of the conditions under which its invaluable service is being performed, the committee passed the resolution in order that no unnecessary friction might be encountered by the board due to additional restrictions upon the manufacture of cement in the midst of war activities.

Routine Inspection and Testing of Cement.

The tremendous expansion of military and naval activities during the year has been accompanied by a corresponding expansion in the construction programs of the War and Navy Departments, and the facilities of the Bureau have been taxed to the utmost in providing the inspection service required by the increased use of cement alone. The appropriations of the Bureau for testing structural materials have been entirely inadequate to cover the costs of this work, and its continuance throughout the year was made possible only by reimbursements from the War and Navy Departments and the Shipping Board. Furthermore, the shortage of available and experienced inspectors has been acute owing primarily to the fact that the salaries established for this class of employees are not attractive to men over the draft age. Nevertheless, the local boards have in the majority of cases appreciated the military value of this inspection service and have granted many of the Bureau's inspectors deferred classification, without which the work would inevitably have suffered.

During the fiscal year 1917–18 cement was inspected at 78 mills throughout the United States, as compared with 16 mills in 1916–17. The increased service which has been rendered during the past year is clearly shown in the following table, which contains the monthly shipments of cement inspected and tested by the Bureau during the 24 months from July, 1916, to June, 1918, inclusive:

Table Comparing Shipments of Tested Cement in 1916-1917 and 1917–1918.

Month.	Shipments of tested cement in barrels.	
	1916–1917	1917–1918
July	36,568	81,364
August	14,941	102,259
September	58,765	146,249
October	32,150	32,366
November	27,338	205,959
December	16,102	183,406
January	29,063	113,104
February	43,744	270,964
March	54,525	335,999
April	48,718	605,128
May	64,325	768,395
June	76,646	752,161
Total	502,885	3,597,354

These totals do not include 72,000 barrels of rejected cement in 1916–17 and 331,000 barrels of rejected cement in 1917–18. Rejections for 1917–18 were in fact larger than indicated, as records are not available of cement rejected by the commercial laboratories

acting under Bureau supervision. The total shipments for the past year include 168,731 barrels for the Panama Canal. Other State and Federal departments served were Commerce, War, Navy, Interior, Treasury, United States Shipping Board, Smithsonian Institution, District of Columbia, Massachusetts State, and various State highway commissions.

It will be observed that the shipments of tested cement during each of the last two months of the fiscal year 1918 were approximately one and one-half times the total for the entire preceding fiscal year. An increase of this magnitude in the inspection work has necessarily involved a large increase in the personnel and facilities for this work, and the organization of the service has been enlarged to cover all cement mills in the country. Thus the new branch laboratories in Denver and San Francisco have furnished inspection at the widely distributed mills west of the Mississippi River, the Pittsburgh branch has provided similar service at the mills in western Pennsylvania and the Ohio River district, the Northampton branch has served the New York and Lehigh (eastern Pennsylvania and New Jersey) districts, and the Washington laboratory has taken care of the Maryland and Virginia mills, as well as the overflow from the Lehigh district. Two well-known commercial laboratories have, under Bureau supervision, furnished inspection service at mills in the southeastern section of the country and also in the vicinity of Detroit, Chicago, and St. Louis.

The employment of these commercial laboratories to provide inspection service in those sections of the country where the Bureau has not yet established its own facilities has afforded an excellent opportunity to compare the costs to the Government of testing and inspecting cement as performed by its own laboratories and by outside laboratories. Assuming a sufficient volume of work to justify the maintenance of branch laboratories, the cost figures of the past year show that the Bureau laboratories are performing the required service at very approximately one-half the contract prices now being paid the commercial laboratories. The volume of work near the close of the year was such that the payments to these two agents was approximately equal to the cost of fully equipping a new branch cement testing laboratory each month.

Viewing the matter from still another angle, the saving which would accrue to the Government by its own cement testing through the Bureau of Standards rather than through commercial laboratories would vary from 1 to 2 cents for every barrel of cement so tested, the actual saving between these limits depending primarily on the percentage of full capacity at which the laboratories were operating. No more potent arguments can be advanced for adequate appropriations to establish the necessary Government branch laboratories in the cement-producing districts.

Another important point may be cited with reference to appropriations. The United States Railroad Administration has requested the Bureau to inspect and test cement for the railroads, an obviously advantageous and economical arrangement for the Government, since it permits the maintenance of pretested and certified stocks of cement ready for immediate shipments at every mill in the country. At the close of the fiscal year, however, no decision had been reached as to the manner in which this service should be pro-

vided for; but it is apparent that adequate appropriations for meeting these additional requirements are necessary before the facilities of the Bureau can be enlarged to the extent necessary for handling the large volume of railroad work.

Development of Testing Methods, Standardization of Testing Apparatus, etc.

Little progress has been made in the development of testing methods owing to pressure of routine work, efforts in this direction being limited to comparisons with the commercial laboratories of methods used and results obtained in the regular inspection work. It appears, however, that radical improvements in routine testing methods are greatly needed, and work of this nature must be undertaken at the earliest opportunity.

Some interesting preliminary work has been done in the calibration and comparison of testing machines. In the investigation work on building stones a very uniform sample of marble was discovered, from which a considerable number of test specimens were carefully prepared and submitted for compression tests to various laboratories. The range in results obtained on these specimens indicates a wide variation in the performance of testing machines, and the development of reliable calibration methods, particularly for large machines, is a problem requiring careful and urgent attention.

Investigation of the Value of Fine Grinding of Portland Cements.

The series of tests, started in 1916, to determine the effect of increased fineness on the cementing value of cement in mortar and concrete has been continued. The two year results show the same marked decrease in strength with the finer ground cements as did the tests of the previous year.

With knowledge of the general results of this investigation the Department of Concrete Ship Construction of the United States Shipping Board, Emergency Fleet Corporation, requested further comparative tests on various cements produced in the southern districts, both as normally ground and as reground to a fineness of 90 per cent passing the No. 200 mesh sieve. These cements were tested in 1:1:2, 1:1–1/2:3, and 1:2:4 concretes and in 1:2 mortar. In practically all cases the increase in compressive strength obtained with the finer cements was from 50 to 100 pounds per square inch for each per cent increase in fineness. From all the data obtained in this investigation the order of increase in strength which may be expected from finer grinding by ordinary methods is now fairly well established, and the question of requiring higher fineness in the standard specification for Portland cement is a purely economic one. There remains, however, the highly interesting and almost wholly unattacked problem of producing cements of much higher fineness than is possible by ordinary methods of grinding. It may confidently be expected that if practical methods can be found of reducing cement clinker to a very fine state of subdivision, a decided improvement in quality will result; to determine what degree of improvement may be obtained is properly the next step in this investigation. The importance of further progress along these lines is commensurate with the difficulties to be overcome in developing new methods of grinding, and concentrated effort will be required to deal

with the new problem effectively. Fortunately some progress was made before the war by the development of an air separator and an air analyzer for the production and mechanical analysis of very fine cements, to which reference was made in the last annual report. These devices will enable a good beginning to be made as soon as conditions permit, but the problem is of such magnitude that little progress can be hoped for during the period of the war.

Standard Cement Sieves.

Forty-three No. 200 sieves were standardized during the year. Owing to the fact that the scarcity of 200-mesh cloth is now acute, there is every prospect that the supply of high-grade cement testing sieves will be cut off entirely. The Bureau is already planning to use sieves for routine testing which do not conform to the standard specifications, and recommends that all users of cement sieves procure the standard fineness samples for the purpose of checking those sieves which are not certified prior to purchase. Even if the correction factors which may be obtained by the use of these samples are considerably in excess of those permitted in the standard specifications, it is believed that the corrected fineness determinations will be sufficiently reliable for mill control and routine testing.

Standard Fineness Samples.

The standard fineness samples of cement, prepared and issued by the Bureau to enable the users of cement sieves to check the performance of their own sieves, are furnished in two degrees of fineness: No. 46–d, of which 79.2 per cent passes the standard No. 200 sieve, and No. 47–b, of which 88 per cent passes the standard No. 200 sieve. These samples are issued in hermetically sealed glass jars, each containing approximately 160 grams of cement, and each is accompanied by full directions for use. In view of the present scarcity of good sieves, particularly of sieves conforming to the standard specifications, these samples should be more widely used.

During the year approximately 50 of these samples were used by the Bureau, 43 were sold at a nominal price to owners of No. 200 sieves, and 15 were donated for university work.

Durability of Stucco and Plaster.

The investigation of stucco and plaster, originally begun in 1911 and continued on a larger scale in 1915 and 1916, has included experimental work only in connection with the construction of three temporary testing laboratories erected on the Bureau grounds during the past year. In view of the present interest in housing problems it is unfortunate that greater progress could not have been made in the development of improved specifications for stucco, but important as this work undoubtedly is, it does not possess the essential and immediate value of the work which has necessarily displaced it. The most important contribution that could be made under the circumstances was the preparation and presentation of a paper at the annual meeting of the American Concrete Institute in June, 1918, giving a résumé of what has been accomplished in this investigation, and containing suggestions for the improvement of stucco based upon the results of experimental studies and field examinations already made.

Durability of Concrete in Sea Water.

In the early part of the year a comprehensive report was prepared and published in one of the leading technical periodicals on the condition of sea-water concrete structures along the coasts of the United States. This report was based on observations and studies made by representatives of the bureau and the Portland Cement Association during the preceding year, and was the forerunner of a more complete and detailed report to be published as one of the Bureau technologic papers dealing with this general subject. Unforeseen changes, however, and demands upon the time of those engaged in this investigation necessitated an indefinite postponement of the preparation of the final report.

Durability of Concrete in Alkali Waters.

This investigation, started in 1913, was undertaken primarily because of its importance to various branches of the Government using cements and concretes in irrigated districts and the arid regions of the West, where the alkali often becomes concentrated in the soil. The investigation, which is conducted in cooperation with the Reclamation Service, the Drainage Division of the Department of Agriculture, and the Portland Cement Association, has included the preparation of 8,000 specially prepared drain tile made in a commercial tile factory under the bureau's supervision, and a larger number of concrete blocks using aggregates available for concrete in various parts of the West.

A progress report, Technologic Paper 95, issued in 1917, includes tests made in 1916 after a period of exposure of three years for the drain tile and one year for the concrete blocks. These results show that concrete and cement drain tile will disintegrate in some of these soils unless the best of materials are used and special care is exercised in fabrication.

Although this investigation is only fairly well started, no field work has been done since the fall of 1916, owing to other demands upon the time of those in charge. It is hoped that this work may be again resumed in the near future, as the problem of conserving concrete structures exposed to alkali waters becomes more important as time goes on and the magnitude of the investment in these structures increases.

Acceleration of the Hardening of Concrete.

As the result of some experiments made to develop a method to accelerate the rate at which concrete increases in strength with age, it was found that the addition of small quantities of calcium chloride to the mixing water gave the most effective results. A comprehensive series of tests was inaugurated to determine further the amount of acceleration in strength of concrete obtained in this manner, and to study the effect of such additions on the durability of concrete and the effect of the addition of this salt on the liability to corrosion of iron or steel embedded in mortar or concrete.

The results to date indicate that in concrete at the age of 2 or 3 days, the addition of calcium chloride up to 10 per cent by weight of water to the mixing water, results in an increase in strength over similar concrete gauged with plain water of from 30 to 100 per cent, the best results being obtained when the gauging water contains from 4 to 6 per cent calcium chloride.

Compressive strength tests of concretes gauged with water containing up to 10 per cent calcium chloride, at the age of 1 year, give no indication that the addition of this salt has had deleterious effect on the durability of the concrete.

Corrosion tests that have been completed indicate that the presence of calcium chloride, although the amount used is relatively small, in mortar slabs exposed to the weather cause appreciable corrosion of the metal within a year. This appears to indicate that calcium chloride should not be used in stuccos, and warns against the unrestricted use of this salt in reinforced concrete exposed to weather or water.

Moisture and Temperature Changes on Concrete.

Field work in this investigation has consisted of making strain gauge measurements on concrete roads and pavements to determine the change in volume of the concrete under changing moisture and temperature conditions, and to determine the most effective distance spacing of transverse joints in the slabs. The measurements show that the concrete follows a rather definite annual cycle of volumetric change. Laboratory work has consisted in measuring with a portable comparator the volumetric changes in cement mortars, plasters, and stuccos when they obtain their set and the progressive changes in volume as they age. A special apparatus for determining the absolute thermal coefficient of expansion of concretes and mortars has been designed and is in the course of construction; but work on the latter has had to be indefinitely postponed on account of the assignment of shop facilities to military requirements. A report on the work already accomplished is being prepared, but like most other reports unrelated to war work, it is necessarily shelved for long intervals.

Flat-Slab Floor Design.

At the request of the Bureau of Yards and Docks, Navy Department, a series of loading tests were inaugurated to determine the relative merit of three types of flat-slab floors designed for the purpose of procuring a suitable design to adopt as a standard for warehouse construction. The floors to be tested are in storehouses being built at the Submarine Base, New London, Conn.; Naval Operating Base, Hampton Roads, Va., and United States Navy Yard, Charleston, S. C.

The test procedure consists of loading 9 representative adjacent panels of each type floor with a superimposed load applied in regular increments until a maximum load is attained equal to twice the designed live load plus the dead load. As the load increments are applied, measurements are to be made with strain gauges to determine the stress in the reinforcing rods at 150 points and also the stress in the concrete at 150 points on both top and bottom surfaces of the floor. Deflections in the floor will also be determined at 41 points.

With the data obtained from these measurements, made when the concrete is 60 days old, a comparison can be made between the different designs of floor, which vary greatly in the amount of steel reinforcements used.

Floor and Roof Failures.

The advice of the Bureau has been sought in connection with a number of interesting cases of floor and roof failures.

The floor of the Pension Office at Washington is composed of clay tiles on a concrete base and has developed certain isolated areas in which the tiles have separated and warped away from the base to such an extent that they have broken down under traffic. Expansion measurements upon the flooring materials have been made, but no satisfactory explanation of the trouble has been found.

The floor of a dry dock at the Brooklyn Navy Yard has shown considerable disintegration. An investigation of this failure indicated that freezing and inadequate drainage were largely responsible for the trouble. A report is being prepared for the Navy Department embodying recommendations for repair of this structure.

The floor of the new Arlington Memorial amphitheater, which is composed of Vermont and Tennessee marble tiles, has shown a peculiar development of fine cracks in the Vermont marble. This case was reported just prior to the close of the fiscal year, and the investigation has not been completed.

The collapse of the steel truss and concrete roof of the Metropolitan Theater in Washington was partially investigated for the information that might be obtained. The immediate failure was found to be due to freezing of the concrete and premature removal of forms, although it was apparent that too small a factor of safety had been allowed in the design. The case also calls attention to the need for a more adequate system of building inspection.

Service Tests of Floors and Floor Treatments.

An abrasion machine has been designed and is in process of construction for the purpose of making wear tests on floors of concrete and other materials. The action of the machine is designed to simulate that of ordinary traffic. Progress in this work, however, has been so frequently interrupted, and so much difficulty has been experienced in procuring the component parts of the machine, that there is little prospect of completing the apparatus during the next fiscal year.

In the meantime a part of the program of this investigation is being carried out in the application of numerous concrete floor treatments to a large number of floor areas and panels in one of the new laboratories of the Bureau. These tests are qualitative and comparative only, but are actual service tests, and in the course of 2 or 3 years should yield valuable information. The majority of the treatments consist of the application of proprietary hardeners or dust preventives, together with a number of others that have been recommended by various investigators, for example, linseed oil, soap, water glass, etc. The scope of these tests also includes coverings of various sorts, linoleum, congoleum, mastic coatings, etc.

Concrete Aggregates.

At the request of the department of concrete ship construction, United States Shipping Board, Emergency Fleet Corporation, a comprehensive series of tests was undertaken to develop or find a material that would produce a concrete of high strength and low weight per cubic foot. In this investigation the following materials,

have been tested as aggregates in relatively strong mixtures: Crushed slags of different kinds; crushed clay tile, both hard and soft burned; crushed light brick of several varieties; a special hollow clay aggregate prepared by the ceramic division of the Bureau; a clinker produced by the rapid firing of clay or shale, coke breeze, pumice stone, vesicular basalt, and other volcanic, silicious, and calcareous rocks.

The most promising results were obtained with burned shale aggregates, which in the proportion of 1 part cement and 2 to 3 parts of graded shale yielded a concrete having a compressive strength of 4,000 pounds per square inch and a weight of less than 110 pounds per cubic foot.

A series of tests were also made on two blast-furnace slags, both as fine and coarse aggregate, from producers in Connecticut and Alabama. Aside from some difference in working quality the concrete and mortars from these materials were practically equal in strength to those obtained from sand, gravel, and stone of good quality.

Field Control of Concrete.

In connection with the concrete-ship investigations an apparatus has been designed to check the consistency of concrete in the field; that is, to control the amount of water required in mixing. This apparatus is essentially a piece of drawn tubing 6 inches in diameter and 12 inches long placed in a vertical position upon a horizontal plate. The tube is filled with the freshly mixed concrete and then mechanically lifted from the mass. The amount of settling of the unsupported concrete is a function of the amount of water used, and thus any predetermined consistency within the working limits can be maintained.

Also in the same connection a field testing machine for determining the transverse strength of concrete beams has been designed. The machine is simple in construction and can be easily set up on the site of the work for the purpose of determining the strength of beam specimens poured from the regular run concrete. Experiments with this device indicate that under given conditions a fairly definite ratio exists between the transverse strength and the compressive strength of concrete, and the latter can therefore be checked without resort to laboratory tests.

Effect of Reversal of Stress on Concrete Beams.

Few, if any, tests have been made on double reinforced concrete beams to ascertain the changes resulting from the reversal of stresses. With the advent of the reinforced concrete ship, a structure which must undergo changes of stress due to the hogging, sagging, rolling, etc., data of this nature has become of extreme importance.

A machine for applying loads in opposite directions to double reinforced concrete beams has been designed and the construction is 80 per cent complete. This machine consists of 3 units in order that owing to the long time required for making a test 3 beams can be tested at the same time. Considerable difficulty has been encountered in getting the machine to operate as it was intended, and a number of changes in the original design have been necessary.

Six beams have been made and 1 has been under test for several weeks, having undergone 300,000 reversals of stress. The beam under test is 8 feet 8 inches long, with a cross-section of 6 by 8 inches

and is reinforced with 3 $\frac{5}{8}$-inch plain bars top and bottom, so placed as to give an effective depth of 6 inches. The applied load at the center of the beam is 5,000 pounds and the computed stresses according to the straight line deformation assumption are: Concrete, 2,000 pounds per square inch; tensile steel, 20,000 pounds per square inch, and compressive steel, 6,000 pounds per square inch. The strain gauge measurements taken on the steel show that these values are slightly in excess of the actual stresses, but nevertheless the stresses are considerably larger than those used for actual working conditions.

On the first applications of the load the beam cracked and showed considerable deflection. After the load was repeatedly applied for several days it was found that the cracks had enlarged to a maximum of 0.01 inch and the deflection had increased from 0.20 to 0.25 inch, which was probably due to a slight slipping of the reinforcing bars. Since that time no change in the beam has been noticed and the cracks close so perfectly that they cannot be detected.

It is planned to test beams of $1:\frac{2}{3}:1\frac{1}{3}$ concrete, using fine aggregate, and later to extend the investigation to cover leaner mixtures. Thus far only plain round bars have been used, but in the program now proposed deformed bars will be used to ascertain their advantage in increasing the number of and distributing the cracks. The reduction in size of the cracks would be of great practical advantage for the end in view, even though the number were considerably increased.

Concrete Bulkheads for Ships.

The question of reinforced concrete bulkheads for merchant ships was brought to the attention of the Bureau when the Bureau of Construction and Repair of the Navy Department asked that certain designs submitted for bulkheads of this type be investigated and some design recommended for temporary bulkheads for seagoing vessels.

A design was worked out for the working conditions as submitted by the Navy Department. This design called for a corrugated type of construction, found necessary because of the requirement of making the structure light as well as strong.

The original design was modified by a second design in which triangular fillets were replaced by parabolic sections, thus reducing the weight slightly. The later design was approved and a full-sized specimen 17 feet high and 5 feet wide was made. In order to test this specimen under conditions approximating those of bulkheads subjected to water pressure a large reinforced concrete testing frame was built, into which the bulkhead specimen would fit. The frame and bulkhead were to be bolted together top and bottom and a water seal effected by bolting on a flexible rubber felt. That the test load might be applied in excess of working loads a reinforced concrete cap 9 inches thick was made to seal the top of the frame.

The construction of the bulkhead specimen and testing frame has been completed, and the test will be made as soon as the devices for measuring stresses and deformations are installed.

Concrete Oil-Storage Tanks.

The high cost and necessity for conservation of steel were the fundamental reasons for making a study of concrete to determine its suitability for oil storage.

At the request of the Navy Department, which was contemplating the construction of concrete tanks for fuel oil storage, a study was made of numerous concrete tanks in which mineral oils were stored. To supplement the information obtained from the field survey it was decided to conduct a series of tests on small concrete tanks using a number of mineral oils from the lightest to the heaviest, also some vegetable and some animal oils. With the coming of the reinforced concrete ship has also come an increased need for knowledge of the action of oils on concrete and its resistance to penetration.

The series of tests originally started consisted of 18 1:2:4 concrete tanks of 10 gallons capacity, which were filled with 11 varieties of mineral oils, 5 of vegetable oils, and 2 of animal oils. Because of the probability that oils will be part of the cargo of concrete ships a new series of tests was started using tanks of concrete similar to that employed in the ship construction; i. e., 1 part cement to 2 or 3 parts of aggregate below one-half inch in size. Some of these tanks of the richer concrete will be tested under a head of about 35 feet and various coatings are to be used to determine their effect in minimizing the penetration of the lighter oils.

Experience with ordinary concrete tanks shows that for the heavier oils there is but a slight loss, but with the lighter oils it is proved that some oil-proof coating is essential to insure against losses that are considerably in excess of those of steel tank storage, which is considered as the best storage.

No injurious effects have been noticed with the exception of one tank in which coconut oil was stored. In this tank a slight disintegration of the walls was noted at the end of one month. The penetration of this particular oil is slight, but wherever it is allowed to come in contact with concrete it will without doubt cause decomposition of the cementing material.

It is hoped that from this investigation results of economic value will be obtained, not only for the departments immediately concerned, but to the oil industry at large.

Automatic Freezing and Thawing Apparatus.

An apparatus has been constructed for the purpose of making a large number of alternate freezings and thawings on samples of stone, brick, concrete, etc., to determine the effect of frost action on such materials. The apparatus automatically shifts the specimens from a cold chamber to a hot chamber at the intervals required for freezing and thawing. Time has not been available to determine completely the most effective operation of the apparatus, but preliminary experiments indicate that the relative durability of different materials, in so far as durability is related to frost action, can be determined in the laboratory in a short period of time.

Investigation of Building Stones of the United States.

During the year tests have been made upon practically all of the important commercial sandstones of the United States. A report of tests on 50 American marbles has been completed and submitted for publication. An investigation is also being carried out to establish a basis for grading the Indiana limestones. Seventy-two samples of this material have been collected from various quarries of the State, and physical tests on many of these samples have been completed.

Miscellaneous Investigations.

A number of limited investigations apart from those specifically mentioned in the foregoing paragraphs have been or are being conducted:

1. A series of tests is being made in connection with the concrete ship work to determine the quality and properties of "gunite," that is, concrete placed with the cement gun, in comparison with concrete fabricated in the usual manner. The tests consist mainly of compressive strength determinations upon gunite built up in successive operations, the study of different methods of operating the machine, and the value of different mixtures.

2. The bureau was requested to determine the value of a proprietary material recommended as a plastic lining for the hulls of wooden ships. The basis of the material was a magnesian oxychloride cement, and, as anticipated, complete and early failure occurred upon exposure to salt water. The manufacturer of this compound also represented that it was of special value as a roofing and flashing material, whereupon he was requested to prepare a small model for test. This model was exposed to the weather on the roof of one of the bureau laboratories, and showed complete failure within a few months.

3. A method of treating plaster of Paris, which was claimed to give quick strength and hardness to casts made therefrom, was found to have little or no value of itself. However, when the treated material was mixed and allowed to set under heavy pressure in a testing machine a product of much greater density and hardness was obtained. Under the conditions of the latter test the value of the treatment could not be definitely established.

4. A proprietary material which analysis showed to be essentially a mixture of one part asbestos and three parts Portland cement was submitted as a suitable compound for the production of a light strong concrete. Tests demonstrated that the mixtures recommended by the manufacturers yielded a concrete weighing considerably less, but of much lower strength than normal concrete.

5. Incident to the work for the Concrete Ship Department of the United States Shipping Board, Emergency Fleet Corporation, 14 concrete mixers were tested to determine their effectiveness in mixing cement mortars. The performance of all of these mixers under the prescribed conditions of the test was satisfactory, judging from the compressive strength of the test specimens prepared from each mix.

6. Some further data have been obtained on the value of the addition of hydrated lime to concrete mixtures. Tests were made on density, compressive strength, and rate of drying of concrete containing additions of hydrated lime up to 20 per cent by weight of the cement. Density was found to decrease slightly with the increase of lime content, whereas very little effect upon compressive strength and rate of drying was noted.

7. In connection with special work for the United States Shipping Board, an investigation was made of the effect of vibrating the forms for varying periods of time on the strength of concrete poured and allowed to set under these conditions. The interesting conclusion was reached that vigorous and continuous vibration for periods up

to three hours did not injure the concrete, and that only slight reduction in strength resulted from intermittent vibration.

8. Some studies have been made of blended cements in which diatomaceous earths from two sources have been ground together with Portland cement in various proportions. The results obtained in concretes at early periods indicated that the blended cements were inferior to normal Portland, but at 6 months a slight reversal was noted. In view of this unexpected development, a more comprehensive investigation will be undertaken to confirm these results.

Results of 1-year tests on concrete made from a slag cement were completed. Concrete made of this cement and exposed to the weather for 1 year completely disintegrated within this period.

Miscellaneous Routine Tests.

During the year the following miscellaneous routine tests have been made:

For the Panama Canal: Granular analysis of 18 samples of sand, 4 samples of sand-blast sand, 4 samples of silica grit, 6 samples of granulated cork; absorption tests on 10 samples of vitrified clay tile conduit; impact tests to determine the toughness of 6 samples of opaque glass, blood-staining tests on 18 samples of clay tiles for use in hospital floors.

For the Bureau of Yards and Docks: Physical tests including granular analysis, specific gravity, weight per cubic foot, and compressive strength in cement mortar or concrete of 10 samples of sand, 6 samples of gravel, 4 samples of crushed limestone. A sample of ground red iron ore was tested in cement mortar to determine its coloring effect. For this Bureau also a number of trips were taken to Norfolk, Va., to inspect concrete work and materials in connection with the construction of the dry dock at that point; tests were made on 6 samples of sand, 2 samples of gravel, and 1 sample of limestone.

For the United States Shipping Board: Thirty-three sands and 10 gravels from the South Atlantic Coast region were tested in concrete and mortar. Three integral waterproofing materials were also tested in concrete for their effect upon compression and absorption of the latter.

For the United States Engineer Office tests of sand, gravel, and stone for use in the new Key Bridge at Washington were made.

In addition to the foregoing individual tests were made on 16 aggregates for mortar and concrete. Thirty samples of sandstone from different portions of a well known quarry were tested for transverse strength to determine the variation of the output.

The Constitution of Portland Cement.

Owing to the demands made on the Bureau by other departments of the Government for help in testing the cement purchased by them, the amount of investigative work on Portland cement was largely reduced. It was found possible to determine quantitatively (approximately) the constitution of a large number of cements made by the Bureau of a widely varying composition, as a check on determinations made previously by another petrographer. These data have been plotted in such a manner as to show the effect of the different amounts of each constituent on the compressive strength of a 1:1.5:4.5 gravel concrete. These curves show very strikingly that

the early strengths are developed by the tricalcium silicate, while at later periods the dicalcium silicate, which hydrates at a much slower rate, adds considerably to the cementitious qualities. At the same time it appears that the "fluxing materials," such as the alumina, iron, etc., should be present in a certain definite amount, above or below which the strengths are reduced at all periods. The high-silica cements in order to develop the same cementitious qualities as the low-silica ones must have less of the "fluxing materials" present.

Hydraulic Cements Other Than Portland.

Since it was found that compounds formed by burning 65 to 75 per cent alumina with 35 to 25 per cent lime in a rotary kiln, when ground, gave hydraulic cements of very high strength at early periods (these results were given last year in the annual report and will be published during the coming year in bulletin form), it was decided to conduct an investigation for the purpose of making cement of silica and lime only. Preliminary work on a small scale showed the impossibility of combining these two materials at the temperature of the rotary kiln, without the aid of some fluxing material. It was then found that boracic acid and calcium fluoride were very desirable and useful fluxes. With the aid of these a number of cements have been burned, not containing alumina, and with a lime content of approximately 70 per cent. There was no difficulty in producing them in a rotary kiln. Their commercial use would be small on account of their very slow time of setting. They are of great interest, however, in helping to elucidate the behavior of the compounds present in normal Portland cement.

Tests of Concrete Ship Sections.

The building of concrete ships has made necessary original investigations to determine the relative strengths and behaviors of ship hulls under the loading conditions imposed by their cargoes and the impact of waves. To simulate these conditions in the laboratory a number of model girders were constructed of cement with various types of steel reinforcement and different arrangements of vertical ribs and these were tested in such a manner as to best approximate the conditions met with in practice. In a number of cases the applied loads sustained were higher than those anticipated by the designers and valuable information was obtained for marine architects and engineers.

Tests of Columns.

The report covering the results of the investigation upon 18 large bridge columns has been published as Technologic Paper No. 101. The columns under consideration in this report were half-size models of different chord members of the new municipal bridge at St. Louis, the Chicago, Burlington & Quincy Railroad bridge at Metropolis, Ill., and the new railroad bridges at Memphis, Tenn. The specimens tested ranged in length from 15½ feet to 24½ feet and in cross-sectional area from 42 to 110 square inches. They were constructed of carbon, chrome, silicon, nickel, and Mayari steels. Some of the columns are the largest which have ever been tested. The strengths as determined from the tests ranged from 31,000 to 46,000 pounds per square inch for the carbon-steel columns and from 48,000 to 65,700 pounds per square inch for the alloy-steel columns. The largest load recorded in absolute value, 6,768,500 pounds, was borne

by one of the nickel-steel columns having an area in cross-section of 110.3 square inches and a length of 24 feet, the ends of the column being square. It was found that the strengths of 12 columns which failed as units were approximately in accord with the yield points of the component steels, the average strength of the columns in compression being nearly equal to the average of the yield points of the component steels as determined by tensile tests. The range in variation in individual cases was between 3.7 and 12.5 per cent in absolute value. Four of the columns failed locally by bending at the ends, and 2 more by localized failures in the lattice, these not developing the full estimated strength of the members. Ten columns of the series failed in smooth flat curves without irregular action of any kind, showing it is easily possible to obtain integral action of the steel in large built-up members.

An investigation has also been under way in cooperation with one of the large bridge manufacturing corporations to obtain information as to the strength and other properties of columns constructed of rolled angles and used so extensively in built-up trusses, towers, and other frameworks. To date 167 columns varying in length from 3 to 25 feet and in dimensions from $2\frac{1}{2}$ by $2\frac{1}{2}$ inches to 6 by 6 inch angles have been tested. It appears desirable after consultation with the manufacturers to make further tests before completing the investigation.

Tests of Cement and Concrete.

The routine testing of cement and concrete for the public and the different departments of the Government has been greater during the past year than in any previous one in the history of this branch of the Bureau. Owing to the inability to secure experienced testers to carry on this work, it was necessary to curtail to a marked degree all investigative work in this connection. There was sampled and tested during the year 361,000 barrels of cement for Government contracts, 221,000 barrels were shipped, 27,580 barrels were rejected for not having fulfilled the requirements of the specifications, and 30,000 barrels were withdrawn by the manufacturers, after sampling but before testing, as the latter had found the cement unsatisfactory. The amount of rejected and withdrawn material may seem to be excessive, but considering the present condition of the labor situation, necessitating the use of many new or partially experienced men, this is not too large. It does illustrate the need, however, of constant testing to insure the securing of satisfactory material.

MISCELLANEOUS MATERIALS.

(Investigation and testing of miscellaneous materials, including lubricants, leather, rubber, textiles, and paper; the design of apparatus and machines for testing such materials; the development of methods of test; and the preparation of specifications for the purchase of miscellaneous materials by the Government.)

LUBRICANTS.

Lubrication of Airplane Motors.

Considerable work has been done on the problem of airplane-motor lubrication. This Bureau cooperated in the laboratory testing of oils in connection with a series of motor tests carried out by the Lubrication Section of the Signal Corps at the Washington Navy Yard. Motor tests are now being made at the Bureau for the pur-

pose of comparing the value as lubricants of both asphalt base and paraffin base oils, as well as colloidal graphite. It is hoped by a comparison of laboratory tests on oils with engine performance to discover the physical and chemical properties indicative of the most satisfactory lubricant, and to prepare specifications which shall insure the purchase by the Government of the best lubricants which can be manufactured.

Specifications for Lubricating Oil Purchased by Government Departments.

The work of writing oil specifications for the General Supply Committee has been continued, and all oils are now purchased by specification. The method of buying on a basis of guaranteed lubrication was found unsatisfactory and has been completely abandoned. The question of viscosity of gasoline and its influence on engine performance is under investigation.

Investigation and Tests of Lubricating Oils.

The standardization of the Saybolt universal viscosimeter, mentioned on page 142 of report for 1917, has been completed, and the results have been published in Technologic Paper No. 112 and also in a paper presented before the American Society for Testing Materials in June. Technologic Paper No. 86 on the test for resistance of an oil to emulsification has been reprinted to meet the continued demand.

Testing of Lubricants.

During the year 555 samples of lubricants have been tested, and 170 letters have been written in answer to request for information concerning the testing of lubricants.

LEATHER.

Investigation of Leather Goods.

The annual report for the fiscal year ending June 30, 1917, contained an announcement of the inauguration of leather investigations with the cooperation of the National Association of Tanners, together with a discussion of some of the preliminary work which had been undertaken at that time. Since then the work has been developed and expanded. With an increase in personnel, funds, and equipment, it has been possible to expedite several problems, both physical and chemical, closely related to Army problems. However, owing to the lack of laboratory space it has not been possible to keep pace with the program which the Bureau has outlined. As soon as the new Industrial Research laboratory is ready for occupancy such difficulties will be obviated and the expansion can proceed satisfactorily.

The chief problem which the Bureau has undertaken in connection with Army shoes is the investigation of the wearing quality of sole leather as related to the chemical treatment in the tanning and finishing processes.

There are six particular experiments in connection with oak-tanned leather which are now under way to throw light upon this problem. These are:

(1) A comparison of the wearing quality of belting tannage with sole tannage.

(2) A study of the effect on wearing quality of loading with glucose as compared with the process of finishing with no glucose.

(3) A determination of the effect of oil on the wearing quality of sole leather.

(4) A comparison of the wearing quality of leather containing a high percentage of water-soluble materials with leather containing a low percentage of water-soluble materials.

(5) A comparison of the wearing qualities of leather of different vegetable tannage, viz, oak and hemlock.

(6) A comparison of the wearing qualities of vegetable-tanned leather with mineral-tanned leather.

The hides used in the above experiments have been carefully selected by representatives of the Bureau and data regarding the history of the hides have been obtained. The experiments are being conducted in three ways:

(1) By service tests conducted with soldiers at Camp Meade, Md.

(2) By abrasion tests upon the bureau's wearing machine.

(3) By complete chemical analyses.

The exact location of the test soles and specimens on the hide is known, so that a comparison of the results should give valuable information.

The Bureau has carried out a rather complete investigation of the wearing quality at different points in the bend and has obtained some very interesting results.

There have also been in progress wearing tests both with the leather-testing machine and by means of service tests upon postmen and soldiers in camp to determine the wearing quality of various brands of fiber composition soles as compared among themselves and as compared with sole leather. Some interesting and instructive data have been obtained and have been reported to the War and Navy Departments.

These experiments are to be greatly enlarged in the near future, and tests are to be made to determine the adaptability of fiber half soles to camp repair work.

Wearing tests have been conducted on the leather-testing machine to compare the wearing quality of lightly and heavily rolled sole leather. In addition to observing the relative wearing quality of lightly and heavily rolled leather, the rate at which the wear progressed was also studied.

In cooperation with the Ordnance Department, this Bureau conducted tests on sides of russet harness leather and russet strap leather. The sides were blocked off, numbered, and photographed and subsequently subdivided into test specimens which were tested for tensile strength, buckle-shearing resistance, and tearing resistance, with the view of ascertaining whether any relation exists among these three physical properties.

A detailed report of the results of these tests has been transmitted to the Ordnance Department.

Specifications for safety belts for aviators have been furnished the Chief Signal Officer of the Army.

At the request of the office of the Quartermaster General rubber cements used in cementing leather to leather, leather to rubber, and rubber to rubber were tested to ascertain the comparative values of different brands.

The Bureau is studying the question of water absorption of sole leather, the use of waterproofing materials, the heat conductivity of leather as compared with leather substitutes, viz, fiber composition soles, and other problems of a kindred nature.

Service tests have been made for the War Department to determine the relative water resisting properties of vegetable-tanned as compared with chrome-retanned upper leather. The regulation Army shoes used for this test were made with vegetable-tanned leather on one shoe and retanned leather on the other.

The Bureau has cooperated with the Bureau of Fisheries in developing methods of tanning shark and other fish skins. As a result of this work tanned skins have been produced of a quality that renders them well adapted as a substitute for certain classes of leather. Numerous tests of these tanned skins have been made to determine their physical properties.

Routine Tests of Leather.

A part of the time of the personnel is consumed in conducting routine tests for various Government departments, particularly the office of the Quartermaster General and the Ordnance Department of the Army and the General Supply Committee and the Panama Canal. These tests consist chiefly in chemical analyses, the determination of tensile strength, ultimate elongation, tearing resistance and other physical properties of leather belting, harness leather, strap leather, lace leather, and leather fan belts. During the year a great many samples of leather have been so tested and reported. There have also been made tests of various materials more or less closely connected with leather goods, e. g., shoestrings, rubber heels with steel heel plates, fiber middle soles, etc.

RUBBER.

Investigation and Testing of Rubber.

The physical work of the Bureau on rubber consists of:

(1) The determination of its physical properties and the investigation of methods of testing.

(2) The investigation of rubber products of various kinds at the request of Government offices to determine their adaptability under special service conditions.

(3) The development of standard specifications for the purchase of rubber goods by various Government offices. At this time the Bureau is acting in advisory capacity in the development of standard specifications for rubber and leather goods for the War Department.

(4) The testing of samples submitted by Government offices to determine if the material meets the requirements of the specifications upon which it is purchased.

Cooperation with Technical Societies and Testing Laboratories Representing Manufacturers and Consumers.

The Bureau has continued its cooperation with technical societies and testing laboratories in developing specifications for and methods of testing rubber goods. This work serves the double purpose of keeping the Bureau in touch with progressive manufacturing practice and of rendering the Bureau's laboratory facilities available to the industries.

Experimental Rubber Plant.

The Bureau's experimental plant, which includes machinery and apparatus for compounding and vulcanizing rubber, has been utilized during the past year, but the work has been handicapped to some extent by the frequent demands of Government office for investigations and tests of manufactured rubber products of various kinds.

During the past year a number of compounds have been mixed for the use of the chemical section for checking their methods of analysis. Tests of some of these compounds have resulted in the development of methods for the analysis of lampblack, glue, and other nitrogenous matter. These results appear in the revised copy of methods of analysis formulated by the chemical section. In addition about 40 rubber compounds in which different organic accelerators were used, were mixed, vulcanized, and tested to determine their physical properties. It is proposed to make compounds containing materials in which sulphur appears in various forms, for the purpose of determining what effect they have on sulphur determinations.

In the manufacture of rubber goods organic accelerators have come into general use. As yet very little has been published concerning the effect of these accelerators on the quality and life of rubber articles. This Bureau plans during the coming year to carry through a complete investigation on organic accelerators. The compounds will be mixed here at the Bureau, all precautions for obtaining accurate results being carefully taken. Not only will the ordinary tests of these various compounds be carried out, but an attempt will be made to see if there is any relation between the natural aging of rubber materials and accelerated aging, such as the effect of dry heat, sun's rays, and ultra-violet rays. The vulcanizing press is to be equipped with mercury thermometers and means for automatic temperature control which will enable careful regulation of the actual vulcanizing temperatures.

The curtailing by the War Trade Board of the amount of crude rubber that may be imported, coupled with the successful results being obtained with cultivated Guayule in California, has opened up another problem. The Bureau plans to investigate the possibilities of substituting Guayule for the higher grades of rubber in certain classes of goods.

Solid-Rubber Truck Tire Tests.

At the request of the Quartermaster General of the Army, the Bureau undertook the testing of a number of solid rubber truck tires, with the view of securing standard specifications for military use. These tires were not only subjected to the ordinary laboratory tests but were tested for elasticity, hardness, and resistance to abrasion. From the results of the Bureau's tests considered in connection with the observed behavior of similar tires on the Mexican border, specifications were drawn up for the purchase of solid truck tires. These specifications with slight modifications have also been used for the purchase of gun carriage tires.

In connection with the investigation of solid rubber tires the Bureau has made for, and in cooperation with, the Inspection Division of the Ordnance Department of the Army a series of tests to study the adhesion between the tread stock and hard rubber base in various makes of tires. A great difference in this adhesion was found in the case of different tires which is in accord with the re-

sults of experience under service conditions. A study was also made of the different degrees of elasticity in the tread stock of different makes of tires. Specifications for solid tires now include requirements for adhesion and elasticity which are determined by tests at the factory.

In order to maintain a satisfactory control over the quality of rubber compounds used, inspectors for the Quartermaster and Ordnance Departments submit regularly to the Bureau samples of rubber for test and analysis as a check on the results obtained at the factories.

Pneumatic Tires and Tubes for Automobiles, Motorcycles, and Bicycles.

The bureau has undertaken the investigation of pneumatic tires and inner tubes for the office of the Quartermaster General, with the object of drawing up standard specifications for tires and tubes for Army use. Between 30 and 40 of the standard nonskid makes of both cord and fabric tires, 35 by 5 inches, and 20 inner tubes were bought in the open market and submitted for investigation. It was apparent that our regular force was not sufficient to carry out this investigation within the time required and 5 enlisted men were detailed to assist in cutting and preparing samples for test.

The tires and tubes have been tested in various ways. The rubber from the tubes and the treads and side walls of the carcass have been analyzed and subjected to physical tests while in their normal condition and after having been given various accelerated heating tests. A number of adhesion tests were made with samples taken from various parts of the carcass between the plies of fabric, fabric and side wall, fabric and cushion, and breaker and tread. The effect of heat on the frictioning compound between the plies of fabric was also determined. From these results specifications have been drawn up for cord and fabric tires and inner tubes for Army use. The investigation is not entirely complete. A number of the tests that had been planned are still to be conducted. It is proposed to carry out actual natural aging tests on such material from tubes and casings as may be left to check against the heating tests which will give valuable information for future use.

A number of standard makes of nonskid motorcycle tires and inner tubes were submitted by the Engineering Bureau, Motor Transport Section of the Quartermaster Department, for test, with the object of drawing up specifications for motorcycle tires and tubes for Army use. These tires and tubes were measured and examined carefully, all necessary and important measurements were taken, and the tires and tubes were subjected to various accelerated aging and physical tests as well as chemical analyses. The rubber from the tubes, treads, and side walls of the casings were subjected to tests for elasticity, strength, and elongation after 0, 4, 9, and 14 days in dry heat at 160° F. and for the same periods of time in dry heat at 228° F. From the results obtained to date specifications have been drawn up for the purchase of motorcycle tires for both the Quartermaster and Ordnance Departments of the Army. Various adhesion and fabric tests were also made. The tests are not entirely completed but they are expected to be finished within the next month.

A number of single-tube and double-tube single and double clincher bicycle tires and bicycle inner tubes were tested for the Engineering

Bureau, Motor Transport Section of the Quartermaster Department of the Army. The results of these tests will be used in preparing specifications for Army use.

Airplane Materials.

During the past year a number of airplane cords, high-tension cables for aviation engines and airplane shock absorbers were tested for the Aviation Section of the Signal Corps.

Gas-Mask Materials.

The great demand for gas masks and gas-mask equipment, caused by the entrance of the United States into the present world war, has opened a new line of work for this Bureau. The Bureau has been carrying out in cooperation with the Gas Defense Service and the Bureau of Mines Experimental Station at American University various investigations on rubber materials, head strap elastics, check and flutter valves, and eyepiece materials. The Bureau has also acted in an advisory capacity in drawing up specifications for and in designating methods of testing the various materials used in connection with gas masks. Among the various materials tested for the Medical Department of the Gas Defense Service are rubber rings for lens washers, elastic webbing for head straps, rubber mouthpieces, rubber nose pads, and rupper stock for mouthpieces, check valves, and flutter valves. The following materials were tested for the Bureau of Mines: Rubber mouthpiece stock, elastic webbing for head straps, celluloid for eyepiece stock, adhesive tape and rubber flutter valves.

Tests of Medical Supplies.

During the past year the Bureau has tested a number of samples of adhesive tapes, hospital sheeting, open-center invalid ring air cushions, and hot-water bottles for the Field Medical Supply Depot of the Army. On several occasions samples submitted by manufacturers have been sent to the Bureau to have them rated in the order of best quality as determined by the results of tests.

On one occasion bid samples representing a proposed purchase of 70,000 hot-water bottles and invalid air cushions were submitted with a request for an immediate report as to the relative suitability of the various makes for purchase, based on considerations of quality and cost. The desired information was furnished the following day. The results of our examination and preliminary tests were in accord with and verified by a detailed report, which was furnished later as a result of more extensive tests, including accelerated aging tests in hot air and hot water.

Tests of Hose and Packing for the General Engineer Depot of the Army.

At the request of the General Engineer Depot of the Army the Bureau has conducted numerous special tests of water, suction, and fire hose, representing various commercial brands as well as hose manufactured to definite specifications which were prepared with the Bureau's cooperation. Special tests have also been made of rubber packings for aeronautical instruments to determine the behavior of different compounds under freezing conditions at high altitudes.

Tests of Fire Hose for Government Departments.

For several years past the Bureau has tested all rubber-lined fire hose purchased by the District of Columbia Fire Department. Contracts for this hose are made under competitive bids according to specifications that have been revised by the Bureau of Standards. This method of procedure has resulted in a material saving in cost to the fire department and at the same time has served to maintain a high standard quality and efficiency of hose.

During the past year samples representing 10,000 feet of 2½-inch hose and 3,000 feet of 3-inch hose have been tested for the local fire department under specifications which require that all delivered be tested as a check on the original bid sample.

Tests have also been made on a number of samples of fire hose submitted by the Panama Canal, the Post Office Department at Washington, D. C., and the General Engineer Depot of the Army.

Rubber Insulated Wire.

The Bureau has carried out further natural aging tests on rubber insulation of wire in cooperation with a number of other testing laboratories identified with the American Society of Testing Materials. The object of these tests is to determine the relation between the natural aging under atmospheric conditions as compared with the effect of dry heat at 160° F. The heating tests were carried out several years ago, and this year completes the aging tests. The results of this investigation will be carefully studied and compared with similar investigations that have been in progress at the Bureau for several years.

The Bureau has also tested a number of samples of rubber-covered wire for different branches of the War Department. Numerous samples of plain rubber-covered wire, waterproof insulated wire, high-tension cables, submarine mine cables, underground cables and teleplone cables, have been tested for the Chief Signal Officer of the War Department, the Coast Artillery Corps, the Torpedo Depot at Fort Totten, N. Y., the Motor Transport Service of the Quartermaster Department, the Equipment Division Laboratory, and the Panama Canal.

Tests of Miscellaneous Materials.

There were tested during the past year a total of 1,697 samples of miscellaneous materials, an increase of 80 per cent over the previous year. A large proportion of these tests were for the various branches of the War Department and in many cases were of an urgent military nature. Many of the tests were of a semi-investigative character, requiring special equipment and preparation.

The following materials were submitted by the Equipment Division of the Ordnance Department for test: Cotton woven straps, rope halter ties, lanyards, rope lariats, buckles, rings, hooks, thimbles, metal snaps, etc.

The Engineering Bureau of the Ordnance Department submitted rubber fuse caps, rope lariats, hooks, links, thimbles, a number of samples of dredging sleeves, etc.

A number of specimens of frictioned cloth, O. D. uniform twill and rubberized and combined sateen fabric, were tested for the Inspection Division of the Ordnance Department.

Various samples of rubber-covered wire, submarine cables, underground cables, rubber tubing for water, oil, and gasoline were tested for the Signal Corps of the Army.

A number of samples of leather preservatives, leather waterproofing compounds, rubber cements for shoes, rubber, etc., motorcycle footpads, motorcycle handle bar grips and pedal grips, asphalt-saturated cloth for waterproofing, steering wheels for motor trucks, etc., were tested for the Quartermaster Department of the Army.

Samples of adhesive tape were tested for the Research Division of the Chemical Warfare Service. The Bureau acted in an advisory capacity in drawing up methods of testing and specifications for adhesive tapes.

On several occasions samples of soft-laid flax shot line were tested for the United States Coast Guard. These lines were tested with special grips which were designed at the Bureau especially for the purpose.

The following items are representative of the routine tests made during the past year: Five hundred and fifty-five samples of lubricants; 485 samples of leather; 127 samples of rubber hose, such as air, air-brake oil, water, fire, suction, steam, etc.; 70 samples of packing consisting of asbestos, rubber, etc.; 64 samples of pneumatic tires, consisting of automobile, bicycle, and motorcycle; 65 samples of solid truck and gun carriage tires; 149 samples of rubber-covered wire and cables; 215 samples of gas-mask materials, consisting of mouthpieces, flutter valves, check valves, eyepiece stocks, lens washers, etc., and smaller quantities of numerous other materials.

The greater part of the routine tests were made at the request of Government departments in connection with the award of contracts and to determine if the materials delivered on contracts were in accordance with specifications.

TEXTILES.

Blanket Investigations.

About a year ago, the Quartermaster General of the Army, realizing that there existed a great need for more effective blankets with regard to warmth, durability, and lightness, requested this Bureau to investigate the possibility of replacing the present Army blanket with one better adapted to the purpose. It was suggested that the relative advantages of various kinds of raw fiber and of various manufacturing procedures be given attention.

In accordance with this request, the Bureau has undertaken to classify some of the commercial types of blankets according to their respective abilities to resist the transmission of heat. The various blanket manufacturers showed much interest in this work and readily agreed to furnish us, free of charge, a considerable number of blanket samples. These were tested for heat conductivity on an apparatus specially designed for the purpose. The several results were compared with those obtained with the Army blanket. It was found that the fiber composition did not materially affect the result, the cotton blankets being as satisfactory as the wool within the limits of the test. The factors vitally affecting the results were found to be weight and method of manufacture.

Consideration was next given to studying methods of manufacture. In this work again the manufacturers showed a willingness to cooperate, but it was found that they could not be of material assistance because their plants are designed for routine production and can not be readily adapted to the construction of special fabrics for experimental purposes. This difficulty, it was seen, would apply with equal force to similar work on clothing materials of all kinds, and therefore it was decided to install a small woolen manufacturing plant at this Bureau, where experimental fabrics could be made under rigidly controlled conditions and test results could consequently be interpreted with reference to the manufacturing procedure used. This plant is now being installed and should be in running order very soon.

It has not been possible as yet to investigate the durability of these materials owing to lack of the necessary materials and equipment. This phase of the problem is of great importance from the viewpoint of conserving the Nation's wool supply.

Uniform Fabrics.

An effort is being made to anticipate the demand for work, similar to that outlined under "Blanket investigations," as applied to fabrics for uniforms. The tremendous demands for woolen materials for Army purposes is sure to cause a critical shortage in the wool supply. This will have to be met either by increased efficiency of use, by the use of substitutes or by importation from foreign countries. The last alternative would involve the use of shipping much needed elsewhere. It is the purpose of the Bureau during the coming year to study the use of substitutes and the adaptation of manufacturing methods to specific service requirements in order to alleviate, in so far as possible, the threatened shortage. This work will be pursued with the utmost vigor, provided the necessary equipment can be obtained.

The textile work of the Bureau, particularly as applied to woolen fabrics, has been seriously handicapped for lack of funds. In view of the grave importance of properly clothing the men of our Army and of providing them with blankets and other woolen equipment, it is very necessary that the personnel and materials required be provided. The work has received the universal indorsement of Army officials, manufacturers, and consumers, and it is believed that it constitutes one of the most promising fields for Bureau of endeavor.

The saving effected by an adequate appropriation would be many times the expense involved, considering only the present year. The work done would be of a permanent nature and further saving in subsequent years, due to work done this year, would therefore be cumulative.

Airplane Fabrics.

At the beginning of the present war, it was evident that the flax crops would not be sufficient to supply the demands for airplane wing coverings. Inasmuch as this country grows but very little fiber flax and has no machinery for spinning the proper yarns for airplane fabrics, it became necessary to substitute our most abundant fiber.

Accordingly the National Advisory Committee of Aeronautics requested that the Bureau investigate the possibility of finding a suitable substitute for the linen. The many previous experiments on cotton and silk had supposedly demonstrated that the substitution was impossible. However, the Bureau under these unfavorable conditions enlisted the cooperation of the cotton manufacturers of this country and began a series of experiments. The willingness of the manufacturers to assist was extremely gratifying, and throughout the entire time they have always been ready to provide samples of varying structure in the shortest possible time.

The properties of the satisfactory linen fabrics were studied and the desirable properties of airplane wing coverings were investigated. From these studies the characteristics of the theoretically perfect fabric were determined. It then became necessary to duplicate these properties in a practically possible fabric. As a result, a cotton airplane fabric has been developed which is considered superior to linen, and which has relieved a serious situation in our airplane program.

The linen situation had developed to a point where it was necessary for the countries associated with the United States in the war to look for other fabrics, and England has already adopted our cotton fabric and found it satisfactory.

Many experiments were performed on silk, and other fibers to be had in fairly large quantities, but in most cases the results were not encouraging.

The work along these lines is being carried on with the view to improving present ones, to develop satisfactory fabrics from other fibers and to provile satisfactory fabrics for new types of planes. The enthusiasm of the manufacturers has been very gratifying. Many manufacturers are offering practical cooperation on the various problems involved.

Attaching of Fabrics to Planes.

The existing methods of attaching and tying fabrics to wing structures has caused in the past a considerable amount of trouble. The Bureau has investigated methods of sewing seams, tying, etc., and the materials used in these operations, and has succeeded in making the conditions much more safe and satisfactory.

Inspection of Airplane Fabrics.

At the request of the Signal Corps, detailed methods of inspecting the airplane and balloon fabrics were outlined and put into effect. The methods have been satisfactory.

Balloon Fabrics.

The Bureau, at the request of the balloon sections of the Army and Navy, has experimented extensively on cloths to be used in the manufacture of balloon fabrics. The foreign balloon fabrics were made almost entirely of cotton and it was a comparatively easy matter for our manufacturers to duplicate these fabrics.

These fabrics are not all that could be desired and the cooperation of the cotton manufacturers has enabled us to develop fabrics which are much more satisfactory. These experiments are still in progress

and it is hoped that they may be completed in a comparatively short time. These fabrics promise to be much more easily produced and it is anticipated that they will satisfy the conditions of stresses in a balloon much more satisfactorily than the present ones.

Balloon Seams.

Extensive experiments on the design of balloon seams have been carried out to determine a seam to most effectively resist the system of stresses involved. It was found that in many cases a simpler seam than those used in foreign practice could be designed.

Parachute Fabrics.

The problem of obtaining satisfactory man and flare carrying parachutes was not particularly difficult, as the foreign silk fabrics could be quite easily adapted to our manufacturing facilities. A very material assistance was given to the military departments in selecting the best fabrics and in measuring the relative efficiency of our own products.

Physics of Airplane Fabrics.

Our early experiments on airplane fabrics lead to the conclusion that many of the factors influencing the behavior of fabrics were not satisfactorily explained, for many of the experiments were more or less impractical.

At the present time, the theory underlying the performance of airplane and balloon fabrics is little known, and the more recent developments in airplane design have caused us to turn our attention to this field. The work is progressing rapidly, and it is anticipated that more efficient fabrics will be evolved and that the airplane designer may predict the performance of any fabric with a reasonable degree of certainty.

Packing of Textiles.

At the request of the Quartermaster General a series of experiments were conducted to determine the smallest size of bale in which a given quantity of the various materials could be packed without injury to the fabrics.

The War Industries Board requested that an investigation be instituted to determine the most economical method of packing textiles for the retail trade, with particular reference to the effect of the method on the properties of the material. These experiments were never completed, due to the lack of proper facilities, but much valuable information was collected. The importance of such an investigation is readily realized when it is considered that in many cases large amounts of shipping space may be saved without seriously injuring the materials.

Miscellaneous Military Materials.

A very limited amount of work has been done on such military fabrics, as dugout blankets, stockinettes, gasmask fabric, stockings, tentage, cordage, and the like.

Specifications for many ordinary materials have been written and placed in the hands of proper authorities.

Test Methods.

The growing prominence of the necessity of testing textile materials, together with the introduction of many new fabrics, has made it necessary to develop the art of testing to a much higher degree than heretofore.

Several important methods of testing have been devised, particularly in regard to aeronautical fabrics, in order that the probable performance of the materials may be anticipated.

The development of new test methods has been accompanied by the necessity of developing new testing machines, all of which have proven to be of material assistance in the selection of proper fabrics for the right one.

Microscopy.

The importance of a microscopical examination of textile materials has long been established, but it was not until this year that we were able to install a satisfactory microscopy laboratory. This laboratory has already been of tremendous value, particularly in the examination of German and other foreign fabrics and in connection with the study of rubberized fabrics.

Industrial Laboratory.

The pure research work of the section has been in the past severely handicapped because of the inability of the research man to be supplied with samples of known value. To overcome this difficulty there is now being installed a complete felt, woolen, and cotton mill for the preparation of samples to be investigated as to their properties.

The value of such a laboratory is realized when it is considered that the textile industry has never scientifically investigated its products. It is anticipated that the future will bring forth keen competition in textiles, and it would appear essential that the American manufacturer should know more exactly the factors governing the quality of his output in order that he may more satisfactorily compete with other nations.

The importance of such information is emphasized when it is considered that the large textile nations are now instituting elaborate plans for the thorough investigation of textiles, and that in many cases the results of the investigations will be more or less constrained to distribution in their own country.

The National Council of Cotton Manufacturers of this country, which represents practically every cotton mill in the country, has pledged its support to the furtherance of our work on cottons and has offered every cooperation which we may desire.

The importance of industrial research on textiles is so very great that it is urged that every effort be made to facilitate concentrated investigations.

PAPER.

Investigation and Testing of Paper.

The general work of the paper section is divided into two parts, namely, routine testing and research investigations. Under routine

testing, is included the testing of samples of paper and paper products, for the various government establishments. In most cases this work includes the testing of samples to determine compliance with a standard specification or an acccpted sample. Under routine testing is also included the preparation of standard specifications of paper for particular purposes. In some cases the development of a standard specification may even require the development of special tests designed to meet some special factor, by which the quality of a material may be definitely recorded. The paper section has assisted many of the governmental establishments in the preparation of standard spccifications and is continually urging upon all that paper can not be intclligently purchased upon any other basis.

In the part designated research investigations is included all work other than that of a purely routine nature. Under this heading are taken up the problems of the industry as applied directly to manufacturing technologly. Previous to the beginning of the war, the paper section had under way a number of problems of importance to the industry. The demand of thc Government for paper and paper products has grown so materially during the past year that almost all of the research problems pertaining to commercial technical interests have had to be discontinued. The work on buttermilk casein adhesives, filter paper, paper-making clays, sizing methods, and other problems have not been abandoned, but have of necessity given way to problems having a more direct war bearing.

Utilization of Wall and Plaster Board.

The use of wall board and plastcr board as a building material for the construction of military cantonments, Government warehouses, office buildings, and similar Government needs has developed to a great extent in the past year. Wall board is a general term covering those types of building material which are used as a substitute for wood lath and plaster in partitions and for sheathing on the inside walls of buildings. Thc construction of the vast number of Government buildings demanded in the prosecution of the war required the use of a material that could be quickly erected, havc a low cost, as well as adequate supply. This necessity was met by thè usc of over 100,000,000 square feet of wall board.

Wall boards are made of paper, built up of one or more layers or plies that are ccmented together with a binding agent such as silicate of soda (water glass) or other adhesive. Plaster board is made of 3-ply construction. The inner ply is made of hydrated plaster of Paris or gypsum, while the two outer plies are made of a special paper. The finished boards are in thickness of threc-sixteenths, one-fourth, and three-eights of an inch.

Plastcr board has fire-retarding properties superior to ordinary wood lath and plaster and far superior to the all-paper wall board. The strength of this material togethcr with its fire-retarding properties and other qualities make it an excellent building material and one that will undoubtedly come into more general use as its properties and usefulness become more generally known.

The term wall board applies only to that type of wall covering that is made entirely of old paper stock, ground wood pulp, or other paper making fibers.

Through the War Department, the Bureau was requested to assist in the preparations of specifications and methods of testing to determine those qualities required. Special methods for testing this wall board had to be devised, in order to duplicate as nearly as possible, service conditions. Samples of all the commercial grades were secured and tested and their relative suitability determined. As the War Department has already used great quantities of this material and is contemplating using much more of it in the near future, the need of complete data of the service of this type of building materials can not be overestimated. The actual service rendered by this wall board has been investigated at various cantonments and in buildings lined with wall board and plaster board erected over a year ago. The result of this general investigation has been to improve greatly the quality of the wall and plaster boards used by the Government. Much of these good results have been made possible by the hearty cooperation of several of the large manufacturers.

Development of Special Papers.

As a result of a demand for special papers by several branches of the military departments, the paper section has carried on experimental work to develop papers having special characteristics. An extra strong paper has been produced, having tensile and bursting strength greatly in excess of any commercial papers so far encountered. This paper can be produced commercially and has possibilities not only for certain military uses but also for warp threads in making strong paper textiles. A detailed study has been made of the control of the process of manufacture, with the result that duplicate lots are readily produced.

Special studies have been made of waterproof lining papers used in wrapping goods for overseas shipments of military supplies. This work has demonstrated the fact that it is necessary to use a craped or corrugated paper in wrapping the bales. This crape or corrugated feature adds the necessary stretch to the paper wrapping, thereby preventing the breaking open of the bale of goods when handled roughly.

Paper-Testing Devices.

In connection with the development of papers of high tensile and bursting strength, it was found necessary to develop a tearing test that would enable this quality to be expressed in numerical values. The need of such a test is important and plans have been made to construct an instrument that will measure this quality.

Means by which the sizing quality of paper could definitely be expressed have always been in demand of the paper industry. The chemical analysis of a paper does not give results that can be used to show relative sizing effect. With this need in view, a modified electrical conductivity method of determining the sizing quality of a paper has been used successfully, developed, and indications point to the fact that by this method sizing quality may be recorded in numerical terms.

Filter Paper for Explosives Testing.

Through the efforts of this Bureau, a sufficient supply of a special filter paper was obtained for the Navy Department. This paper is of the highest importance as it is required to determine the stability of high explosives purchased by all the military branches.

Information Furnished on Paper.

Special assistance has been given in by this Bureau to the Federal Trade Commission in connection with the newsprint investigation; to the Council of National Defense in regard to importation and use of china clay in the paper industries; to the Shipping Board relative to the use of clay, casein and rags in the paper industry; to the Pulp and Paper Section, War Industries Board, in supplying technical information (the Paper Section being represented on the Pulp and Paper Section) relative to the pulp and paper industry; to the Bureau of Mines for cooperative work in connection with the development of a paper as a smoke-filtering medium; and to the Joint Committee on Printing, and the several Government departments, as well as the General Supply Committee, in connection with the preparation of specifications for paper and allied materials.

It is impossible to enumerate the whole range of inquiries that are constantly being received, but the following will outline in brief the more important ones:

Paper containers.—Specifications of paper containers to be used for shipment of axle grease and similar substances overseas. A compact paper container was desired in connection with the conservation of tin and steel, and also to provide a small compact package of axle grease to be issued to drivers of motor cars, tractors, wagons, and gun carriages.

Absorbent paper.—During the past year an absorbent material has been produced and placed upon the market by several manufacturing companies. This material is made from bleached chemical pulp. In appearance it resembles ordinary absorbent cotton, with the principal difference in that it is made in very thin layers which are very much lighter in weight than the lightest tissue paper. This material is also very heavily craped. This wood pulp "cotton" is coming into very important use as a surgical dressing to replace absorbent cotton. It will absorb practically as great a weight of moisture as cotton and has an added advantage of absorbing very much more rapidly. The material being of a lower price than absorbent cotton and being somewhat more easily handled, will undoubtedly replace cotton for this class of work. Both the Army Medical Service and the American Red Cross are large users of this material and the paper section has also been able to interest the Public Health Service in this material.

Paper bandages.—The laboratory has recently received samples of paper bandages made from specially prepared paper. A bandage of this kind is not as resistant to moisture as a cotton cloth bandage, yet it has a number of advantages in that it is lower in price and because of the way in which it is made, it conforms more readily to wrapping around irregular surfaces. This paper bandage for surgical

dressings will undoubtedly come into more and more general use. They are not substitutes, but should be considered in the light of new material, having certain advantages over the ordinary absorbent cotton and cotton bandages.

Many inquiries have been received covering all phases of manufacturing details and the paper section has endeavored in every way possible to supply the necessary information desired. Several American manufacturers of vegetable parchment paper used for wrapping meats, fish, butter, cheese, etc., have had difficulty with both the Australian and New Zealand customs authorities in securing a correct classification for the American parchment papers. This matter was called to the attention of this Bureau and after considerable correspondence this Bureau was able to point out to the customs authorities mentioned that their regulations did not in any way restrict the American product. It was also called to their attention that their method of testing did not enable anyone unfamiliar with the subject to make a correct decision as to whether the paper was or was not a true vegetable parchment paper. The Bureau endeavors at all times to assist American manufacturers in broadening their commercial field and is in a position to take up with foreign authorities the discussion of customs regulations which might tend to discriminate against the American product, especially in questions where the regulations may not have been correctly interpreted.

Assistance to paper industry.—Many requests for standard samples and specifications used by the Government have been received and complied with. In addition to this many specifications have been prepared to meet the requirements of paper for special purposes.

The continual increase in the number of visitors is an indication of the growing interest which both the trade and the general public are taking in matters pertaining to paper and paper products. A great many of these visitors are of the type that desire general information relative to paper and paper testing and the possibilities of developing specifications for paper for particular purposes. Since the beginning of the war, however, there has been a steady increase in the number of manufacturers who have visited the laboratory. The general purposes and aims of the laboratory are explained and every effort is made to demonstrate the necessity for carefully controlled experimental work. A number of large paper companies have planned a way by which they propose to install a complete experimental equipment similar to the one here at this Bureau. Such inquiries are given every possible assistance, as it has been demonstrated that a superior and more uniform product is secured from those mills that are considering manufacturing problems from a scientific standpoint.

Summary of Tests.

The Bureau has tested for the Government Printing Office and Government departments 5,277 samples of paper. It has tested for public and private interests 420 samples of paper, making a total of 5,697 samples tested. This is an increase of 83 per cent over the preceding year and indicates the increased use of this branch of the Bureau's activities, brought on by war conditions.

8. METALLURGY.

[Thermal analysis and structure of metals, heat treatment and its effect upon the properties of metals and alloys, including the researches involved in determining the causes of metal failures, cooling and heating curves; the investigation of hardening, annealing, tempering, cementation; the determination of critical ranges; and the preparation of pure metals and alloys.]

Equipment.

In view of the fact that the Metallurgical Division has just completed removal into new and greatly enlarged quarters and is acquiring considerable new equipment, it may be of interest to mention some of these items as an indication of what we are prepared to do in metallurgical investigation and testing. The plan laid down is, to be able to make any metal or alloy, give it any desired thermal and mechanical treatments, and carry out any required test or investigation of its properties. The manufacturing scale adopted, up to quarter-ton units, appears sufficient to warrant reaching "practical" conclusions.

The basement of the northwest laboratory contains the manufacturing units, comprising foundry, heat-treating and mechanical plants, which last includes motor-driven rolling mill with 4:1 speed control, 150-ton steam, hydraulic power press and shearing attachment, driven by 150-horsepower air compressor, a motor-driven 10-ton chain drawbench with attachment for drawing tubes, and shop, with a 10-ton crane over all. The foundry includes both gas and oil fired crucible furnaces, 2 of 200 and 1 of 50 pounds capacity, core ovens, molding equipment, casting pits, etc.; a 150-kilovolt-ampere arc electric melting furnace of 600 pounds capacity is being installed, and it is hoped to be able to install a 1 or 2 ton open-hearth furnace; there is a laboratory attached to the foundry for research work on sands.

The heat-treating plant comprises 1 semimuffle oil-fired furnace 7 by 2 by 1½ feet, with quenching tanks of oil and water 12 by 3 feet provided with circulation pump, salt and metal baths, case hardening furnace, several gas and electric muffle furnaces of various sizes, 5 electric resistance tube furnaces, 2 electric melting furnaces for high temperatures, and there are being installed 2 large 50-kilovolt-ampere electric annealing furnaces to serve the rolling mill; one of these, 14 feet long, is designed for rods and tubes and the other for ingots. Additional furnace equipment for special researches includes 2 high-temperature vacuum furnaces with pumps, rheostats, and other accessories and a number of small furnace units.

For thermal analysis there has just been delivered an Einthoven galvanometer outfit which will be used in various experiments on the properties of rapidly cooled alloys. This section also possesses three complete sets of thermal analysis outfits and has recently designed and put into operation a new type of furnace determining transition points in alloys. New apparatus for determining electrical resistance of alloys has been installed and considerable auxiliary apparatus and supplies purchased, including porcelain, platinum, quartz, thermocouples, galvanometers, resistances, tools, etc.

Among the miscellaneous equipment an optical pyrometer including a micropyrometric outfit, apparatus for determining hardness, Brinell and a scleroscope, also new microhardness instruments are being designed; a 10,000-pound testing machine; a 30-foot-pound

impact machine. (The heavy mechanical tests are made by the Structural Materials Section.)

There is one room fitted up for physico-chemical research, electrochemical analysis, and equipment for examination of fusible plugs. In addition to the general shop facilities of the Bureau there is attached to the Metallurgical Division a small shop containing saw, grinder, miller, drill press, and lathes. The electrical equipment for so much special apparatus is necessarily quite extensive and embraces several power lines with alternating current and direct current and a flexible set of transformers, rheostats, potentiometers, and other instruments, etc.

The metallographic facilities include adequate apparatus for cutting up, grinding, polishing, etching, and photographing metals. The laboratory possesses three metallographic outfits, a Zeies, Leitz, and latest Bausch & Lomb model, and a varied assortment of accessories.

In the laboratory of chemical metallurgy are large electric vacuum furnaces and auxiliaries for preparing pure metals; an outfit for electrodeposition of iron, etc.; furnaces and other equipment for preparing pure magnesia crucibles; apparatus for determination of gases in steel, several for rapid determination of carbon by composition and electrolytic method; furnace for preparation of pure aluminum; in addition to the usual chemical equipment.

Publications.

The practice has been continued of issuing circulars of information concerning metals and alloys. Thus a circular (No. 73) just issued on copper treats of its manufacture, physical properties, metallography, together with information concerning effects of temperature and of impurities on physical properties and contains a comprehensive bibliography. Circulars are in press or in preparation on "Aluminum and Its Light Alloys," "Solders for Aluminum," "Bearing Metals," "Acid Resisting and Noncorrodible Metals," "Protective Metal Coatings," and the circular on metallographic testing is being revised.

Pending the preparation in the more comprehensive form of printed circulars, information on certain subjects of general interest, or about which numerous inquiries are received, is disseminated in "circular letters." The following, prepared this year, are typical: "Sources of Information and Data on the Properties of Metals at High Temperatures." "Mechanical Tests of Metals and Alloys and High and Low Temperatures; Sources of Information and Data."

The following papers by members of the Metallurgical Division have appeared during the year: Typical Cases of the Deterioration of Muntz Metal by Selective Corrosion, Bureau of Standards' Technologic Paper No. 103, American Institute of Metals, IX (p. 148, 1918): Some Unusual Features in the Microstructure of Wrought Iron, Bureau of Standards' Technologic Paper No. 97. Transactions of American Institute of Mining Engineers (p. 1345, 1918); Copper, Bureau of Standards' Circular No. 73, Metallurgical and Chemical Engineering (18, pp. 121, 192, 303, 357, 1918); Rapid Determination of Carbon in Steel by the Barium Carbonate Titration Method, Journal Industrial and Engineering Chemistry, (10, p. 520, 1918); Thermal Expansion of Alpha and of Beta Brass Between 0° and 600° C., in Relation to the Mechanical Properties of Hetero-

geneous Brasses of the Muntz Metal Type, Bureau of Standards' Scientific Paper No. 321, 1918, Journal American Institute of Metals (11, No. 3, p. 396, 1918).

The following are in press: Structure of Commercial Zinc Coatings, Proceedings American Society for Testing Materials, XVIII, 1918; The Use of Mercury Solutions for Predicting Season Cracking in Brass, Proceedings American Society for Testing Materials, XVIII, 1918; Second Report on Ladle Test Ingots, Proceedings American Society for Testing Materials, XVIII, 1918; Aluminum, Bureau of Standards' Circular; Solders for Aluminum, Bureau of Standards' Circular; Initial Stress and Corrosion Cracking of Brass, Proceedings American Society for Testing Materials, XVIII, 1918; A Critical Study of the Ledebur Method for Determining Oxygen in Steel.

The following are in preparation: Conservation of Tin in Solders, Bearing Metals, and Bronzes, American Institute of Mining Engineers; Circular on Bearing Metals; Circular on Acid Resisting and Noncorrodible Metals; Circular on Types, Properties, Specifications, and Tests of Metal Coatings; Manufacture and Testing of Tin Fusible Boiler Plugs; A Modified Sample Collecting Sprengel Pump; The Embrittling Effects of Metal Coatings.

Metallurgical Tests.

The tests of metals executed the past year have been mainly for the military departments, and many of them were of such elaborate character they will be classed as investigations. Of the more elaborate investigative tests may be noted: An examination of the characteristics of centrifugally cast steel—which gives promise of possibilities of advantageous use in replacing several lines of steel forging, cutting down discards, machining and segregation, and eliminating piping, blow holes, and forging; a study of strains in cartridge cases as dependent on manufacturing methods and the adaptability of accelerated stress-corrosion tests for predicting failure; the relation of grain size to distortion in cartridge cases; an exhaustive comparison of the relative merits of cold shearing and nick-and-break method for shell slugs; distinguishing between hard and soft rotating bands for shells; several tests of armor plate and numerous other materials for ordnance, aircraft, quartermaster and engineering departments of the Army and for the various branches of the Navy; fusible tin boiler plugs for steam vessels; recovery of tin; examination of a very large variety of coatings for rust proofing; interesting points were the nonuniformity in electroplated coatings, uniformity of sherardized coatings; brass plating, the relations among the metals showing the superiority of zinc; and a study of the "copper-clad" process; micro examination of large (12-inch) chain links forged, welded and cast, tarnishing tests on Benedict nickel and German silver; heat treatments presenting special problems were very small compass needles, large (30-inch) U-bars, long slender rods and very large sheets; service tests of the lead-base bearing metal, ulco; service tests of a special lead-base babbitt; investigation of cause of failure by cracking of brass locomotive steam gauges; cause of cracking of case-hardened aeroplane engine cam follows; failures of aeroplane crank shafts; service tests of rhotanium and palau (substitute for platinum) crucibles; corrosion tests on several acid-resisting alloys; tests of numerous

commercial light aluminum alloys; causes of cracking of welded Army aluminum canteens; determination of working temperatures of machine gun barrels; tests of magnalium alloys of high optical reflectivity for mirrors, including the preparation of a series of a considerable number of such alloys, a large number of steels and alloys were examined by thermal analysis to locate their critical points; the casting of numerous metals and alloys for instrument parts and researches; samples of meteoric iron for structural characteristics; numerous samples of platinum to determine purity and causes of deterioration; a very serious type of failure known as "flaky" steel occurring in nickel-chromium and nickel steel was studied in great detail; semisteel, cast iron and steel shells; failed gun forgings and other ordnance material to determine cause of failure, suitability for use or special characteristics; valves for aircraft motors; machine-gun barrels; German rifle bullets; cartridge clips, etc.

A summary of the metallurgical tests is given below; their total value in fees is $7,090.50. Of these tests items, 90 per cent were for the various departments of the Government and 10 per cent for private individuals and corporations.

The activities incident to the carrying on of the war have made many temporary changes necessary in the research program; new problems have been taken up and work on the older ones has had in some of the cases of necessity to be for the moment discontinued.

	Heat treatment and thermal analysis.		Metallographic (including physical, chemical, and corrosion tests).							
	Irons and steels.	Non-ferrous metals	Irons and steels.	Aluminum alloys.	Brass and bronze.	Identification of metal and process of manufacture (metal coatings).	Other metals.	Fusible plugs.	Miscellaneous.	Grand total.
For the Government:										
Bureau of Chemistry	.....	.....	.....	.....	.....	.....	.....	.....	4	4
Bureau of Entomology	.....	.....	.....	.....	.....	5	.....	.....	.....	5
Bureau of Mines	.....	.....	.....	.....	.....	.....	.....	.....	1	1
Bureau of Standards	118	.....	6	.....	.....	6	.....	.....	25	155
Council of National Defense	.....	.....	.....	.....	.....	.....	1	.....	.....	1
District of Columbia	.....	.....	.....	.....	2	.....	.....	.....	.....	2
Emergency Fleet Corporation	.....	.....	.....	.....	.....	.....	.....	.....	1	1
Lighthouse Service	.....	.....	.....	.....	.....	.....	.....	.....	1	1
Navy Department	.....	.....	2	7	9	6	2	.....	1	27
Panama Canal	.....	.....	15	.....	.....	57	.....	9	1	82
Patent Office	.....	.....	.....	.....	.....	.....	2	.....	.....	2
Post Office Department	.....	.....	.....	.....	.....	6	.....	.....	.....	6
Smithsonian Institution	.....	.....	2	.....	.....	.....	.....	.....	.....	2
Steamboat-inspection Service	.....	.....	.....	.....	.....	.....	.....	453	.....	453
Treasury Department	.....	.....	.....	.....	.....	.....	.....	.....	3	3
United States National Museum	.....	.....	14	.....	.....	.....	.....	.....	.....	14
War Department	14	.....	222	16	26	8	41	.....	75	402
War Industries Board	.....	.....	.....	.....	1	.....	.....	.....	.....	1
Total	132	.....	261	23	38	88	46	462	112	1,162
For the public	14	.....	35	3	19	11	19	.....	26	127
Grand total	146	.....	296	26	57	99	65	462	138	1,289

Tests of New Alloys.

The war has brought out a number of new alloys, or modifications and processes with new names, which have been submitted for examination usually with view to their military utility. Some of these are: "Liberty metal," palau, rhotanium, various aluminum solders, acerial, magnalium, magnalite, McAdamite, cooperite, al-calcium, magnolia metal, ulco bearing metal, various metal coating processes, the alloys dirigo, bario, ampco, cosmic, zelco, stellite, tinol, aterite, sperlite, Siliman bronze, etc.

Military Boards and Committees.

The International Aircraft Standards Board, organized August 8, 1917, with representatives of Canada, France, Great Britain, Italy, and the United States, has held most of its meetings at the Bureau of Standards. This board has done valuable work in reducing the number and unifying specifications for aircraft materials purchased in the United States. Eighty specifications, of which 67 covered metals, have been issued for the board by the Bureau of Standards. Several important lines of investigation have also been the outcome of the deliberations of this board.

The Emergency Fleet Corporation has organized a committee on Welding—in succession to others of the American Institute of Electrical Engineers, etc.—in which the Bureau of Standards was represented, and a distributed experimental program is under way.

The Advisory Committee for Aeronautics in November, 1917, organized a light alloys committee. Several important experimental contributions have already been made, mainly by the Bureau of Standards, on aluminum and its alloys, and others are in preparation.

On the National Research Council's foreign service engineering and body armor committeees the Bureau of Standards was represented.

Various members of the Metallurgical Division have been called in as technical advisers by the several branches of the War Industries Board, particularly on tin, steel, and platinum, and the Bureau of Standards in consequence has undertaken considerable experimental investigation, especially on tin conservation and substitutes.

In addition to formal committees with regular programs, there have been held a great many conferences, at which the Bureau of Standards' representatives have been present, called by the various military department to discuss with manufacturers technical questions bearing on military materials and specifications.

Military Inventions.

The Metallurgical Division has assisted the several information, patent, and military departments in the examination and development of military inventions relating to metals, manufacturing processes, and various devices made of metals.

Information Furnished by Correspondence.

In addition to information furnished in personal interviews on technical subjects, there is a very heavy correspondence maintained on subjects relating to metals; that of the month of February, 1918, here reproduced is typical both as to range and number of subjects.

Information has been furnished by correspondence on the following subjects: To the Navy, resistance to corrosion of aluminum bronzes, criticism of bronze and brass specifications, corrosion of copper plated clips, bolts, sheets, etc., zirconium steels, nickel-steel for periscope tubes, oxyacetylene welding of steel pipes; to the Army, on quenching media for heattreating steels, noncorrosive metals, copper rotating bands for projectiles, sheet aluminum, steel for caterpillar treads of tanks, seamless and welded tubing, effect of mercury on primer metals, gun-metal tests, tests of brass-coated washers, on nickel-steel stock, melting points of brazing wire, nickel-plated sheets, advice as to publication of "steel in aviation;" to miscellaneous parties, silver-plated articles, use of aluminum scrap, substitution for tin in bearing metals, quality of fusible boiler plugs and substitutes, several items regarding welding processes, aluminum solders, electric conductivity of "bario" metal, etc., production of highest purity aluminum, a certain process of galvanizing, standard brasses and bronzes, heat treatment of steel (several requests), optical pyrometers for metallurgical use, electrical welding of aluminum, manufacture of bronze powder, steel coated by "Epicassit" process, tempering steel, formulæ for galvanizing, galvanized culvert pipe situation, use of boron copper, bearing metals, physical properties of copper, aluminum, zinc, etc., (several requests), platinum substitutes, manufacturers of iridium and of tungsten steel, corrosion of iron and steel, methods of steel manufacture, alloys for aircraft, relative corrosion of metals, metals to take engraving for instruments, cobalt-chromium steel thermal characteristics, foundry mixtures for molds, silicon-bronze characteristics, brass formulæ, aluminum alloys and nonmagnetic alloys, corrosion of "alumoy," casehardening, specifications for Government materials (several requests), manufacture of small metal articles, material for aircraft engine valves.

MICROSCOPY OF METALS.

(The microscopic examination of metals and alloys, investigation of flaws, defects, and other imperfections in commercial metallic materials.)

Corrosion of Nonferrous Metals.

A contribution to this subject has been made in the form of a descriptive summary of typical cases illustrating this type of deterioration of metals. Much of this material has been submitted to the Bureau for examination during the past 4 or 5 years.

Protective Metallic Coatings.

In a study of the effects of rustproofing on the brittleness of wires, started at request of International Aircraft Standards Board, a preliminary examination was carried out with tensile tests of wires, taking the elongation in tensile test as a measure of the brittleness. While some conclusions as to effects of cleaning, plating, etc., could be drawn, the results were not sufficiently definite and a new form of test piece was required. It was decided to adopt the impact test, and an impact machine of the Izod type was designed and built. The experimental program covers the various compositions and sizes of wires in common use, and the investigation is to be extended to include especially the brittleness of small springs. In cooperation with the American Society for Testing Materials a joint program is

being carried out on zinc coatings, their properties, methods of test, structure, and effects of various coatings on the base metal.

Microstructure of Wrought Iron.

The study of the modifications which the presence of phosphorus may bring about in wrought iron has been completed and published. (Bureau of Standards Technologic Paper 97.)

Valve Steel for Airplane Engines.

Investigation of the effect of the rate of temperature change on the transformations and microstructure of an alloy steel used in valves for aeroplane motor very nearly completed. This investigation is expected to throw considerable light on the nature of hardening of steels and the properties of alloy steels. The results obtained will also contribute to theories of the hardening of steel.

Ladle Test-Ingot Investigation.

The second phase of this investigation as outlined in last year's report, has been completed and a report made to the American Society for Testing Materials. Aluminum treatment of ladle test-ingots was shown by this work to give nonsegregated ladle-test ingots of high and medium carbon steel, but such treatment has little advantage for low carbon steels. Recommendations were made as to adoption of desirable types of ladle test-ingots and as to a comparative study during the year at certain works of test-ingots made with and without aluminum treatment.

HEAT-TREATMENT AND THERMAL ANALYSIS.

(Determination by thermal analysis of critical temperature points and ranges in metals and alloys, and the heat-treatment of these materials.)

Iron-Carbon Transformations.

The investigation of the transformations in pure iron-carbon alloys is nearing completion. The results are of practical as well as theoretical interest, as they form a basis for estimating the temperature of the transformations in steels by chemical analysis, which will eventually eliminate the necessity for commercial apparatus for this purpose, and they give a sound basis, which at present does not exist, on which to construct a theory of hardening.

Preparations are being made for the determination of the transformations in pure iron-carbon alloys containing various alloying elements.

New Furnace for Thermal Analysis.

A furnace of a new type for obtaining thermal curves has been constructed at the bureau. This furnace makes it possible to do at least twice as much work in a given time as previous equipment, it uses a very small fraction of the power previously required, and a much greater temperature range and variation of rate is obtained with a more uniform curve than was formerly attainable. This will be described shortly.

Gun Erosion.

In cooperation with the Ordnance (Army) Department a comprehensive investigation is being made of the various factors affecting gun erosion, particularly as applied to machine guns.

PHYSICAL PROPERTIES OF METALS AND ALLOYS.

(Determination of physical properties of metals and alloys; correlation of physical properties with structure and constitution, and effect of temperature, mehanical working, etc., upon these properties.)

Light Aluminum Alloys.

One of the most important investigations taken up because of its military importance and urgency was that of the technical phases of the manufacture and the properties of the light alloys of aluminum, both wrought and cast. Such alloys are of especial significance in connection with the design and construction of aircraft, for which their lightness and strength well fit them.

In order that this work might constantly best serve the needs of the military departments, close contact has at all times been maintained with them, both through the Light Alloys Committee of the National Advisory Council for Aeronautics and by personal conferences. Confidential reports have been issued from time to time—5 to date—of the progress of this work.

One of the interesting results of this work has been the demonstration of the necessity for thorough investigation of fundamental facts and phenomena as the only satisfactory basis for technical progress in the art of manufacture. Thus, at the outset, interpretation of tests results was confronted by an almost total ignorance on the part of our present day metallurgy of some of the most fundamental physico-chemical data of aluminum and its alloys. As the technical phases of the work have proceeded therefore, the theoretical phases, such as constitution, etc., have required more and more attention, until at present it appears that further progress depends upon the solution of several of these fundamental questions.

Several directions have been followed in this work:

Aluminum-Rich Alloys of the Three Ternary Alloy Systems.—This is a study of the possibility of developing better commercial rolling alloys for use in structural construction. A survey was made of the mechanical properties of the rolled aluminum-rich alloys of each of these alloy systems. From 8 to 12 compositions of each system were cast and rolled into sheet at the New Kensington plant of the Aluminum Company of America, a representative of the Bureau directing both the preparation and subsequent testing of the samples. The copper series proved so superior in respect to mechanical properties in these tests that the other two series are practically eliminated from further consideration for purposes for which high strength is desired; only this series, also, is to any extent subject to heat treatment. The results of this investigation are described in Confidential Report No. II. The investigation is completed.

The Heat Treatment of the Duralumin Type of Alloy.—Heat treatment of the alloy known commercially as duralumin has been practiced for several years, but apparently little improvement has been made in the actual heat treatment practice since the initial discovery of this property of the alloy by Wilm. The Bureau's investigation of this question has led to some very interesting discoveries bearing on the theory of the effect of this treatment and to important alterations in existing practice of commercial heat treatment, resulting in improved physical properties and reduced wastage from cracking

during treatment. These alterations have been adopted commercially. Confidential Reports Nos. III and IV have been issued dealing with the results of this work.

The investigation is almost complete, but further work will be done (1) to clear up more definitely the theory of hardening by heat treatment, and (2) to ascertain the best heat treatment for the production of an alloy most resistant to alternating stresses.

Light Aluminum Alloy Castings.—Tests are being made of different casting alloy compositions, cast in the Bureau's foundry, (1) to discover alloys which will give better mechanical properties than those in use at present, (2) to study the effect of heat treatment on these alloys, (3) to ascertain the effect of the impurities, iron and silicon, on the properties of the alloys in the cast form, and (4) to study the effect of melting and casting temperatures on those properties. To date about 40 heats of metal have been poured and tested and the results are indicative of the possibility of obtaining alloys which are both harder and at the same time more ductile, hence tougher, than those in use to-day; this is accomplished both by the choice of a more suitable composition and the application of heat treatment.

This work is being continued on ever increasing scale, as there is a strong and growing commercial and military demand for better casting alloys.

Alternating Stress Tests of Duralumin and of Commercial Light Aluminum Casting Alloys.—The use of both rolled duralumin and of aluminum casting alloys in aircraft construction demands a fuller investigation into the resistance of these alloys to alternating stress than has ever been attempted hitherto. The materials for this work have been assembled or produced at the Bureau, and many of the tests made; the more rapid progress of this work only awaits the completion of the remaining 5 testing machines at the shops.

The Corrosion of Some Aluminum Alloys.—Tests are being made and are almost completed of the corrosion of different compositions of both rolling and commercial casting alloys in the salt spray test. In connection with (6) below, also, exposure tests in sea water have been undertaken of rolled duralumin in comparison with steel, copper, and brass. The results of these latter tests will naturally not be available for several months.

The Protection of Duralumin Against Corrosion.—With the cooperation of the Navy Department and of the Aluminum Company of America exposure tests in sea water have been planned and are about to be executed of duralumin coated with various types of paints and varnishes. The results of these tests will indicate how readily possible the protection of this metal by paint is, and are desired chiefly for the information of those interested in aircraft design and construction.

The Constitution and Metallography of Light Aluminum Alloys.—The necessity for clearing up a number of questions relating to the structure and constitution of aluminum and its light alloys has become increasingly apparent as a basis for further progress in the art of the manufacture of the alloys, and has led to the undertaking of the determination of (1) the structural identity of the constituents of the alloys of aluminum with iron, silicon, copper, magnesium,

manganese, and nickel, and (2) the solubility at different temperatures of these constituents in aluminum in solid solution. Much of this work is completed and one confidential report (No. V) gives the solubility curve of $CuAl_2$, the aluminum-rich compound of the copper-aluminum series. These results, when complete, together with the data of previous investigators, will practically complete our knowledge of the constitution of the aluminum-rich alloys of these metals, and will serve to direct further work in the choice and development of commercial alloys.

The work to date has shown the superiority in strength of both casting and rolling alloys, of either zinc-copper or magnesium-copper as an addition to aluminum. The National Physical Laboratory is studying the zinc-copper combination, as far as rolling alloys are concerned; therefore our further efforts will be to improve the duralumin type of alloy, either by slight alteration of composition or by alteration of heat treatment.

The study of quite new rolling alloy compositions is considered unnecessary for the present.

One further problem that will be undertaken will be the possiblity of spot welding duralumin.

At present beams and other structural members of duralumin for aircraft construction are assembled by riveting. It would be desirable as expediting production of such members to assemble by spot welding if this process could be shown to produce some reliable joints.

Magnesium-Aluminum Alloys for Mirrors.

There is under way an investigation for two branches of the Army, an investigation of possiblities of producing large mirrors of the magnesium-aluminum or magnalium type of alloy preserving high reflecting power and sufficient strength and of nontarnishing properties. Considerable success has been attained.

Investigation of Railway Materials.

Owing to the demands upon the time of those engaged in this work, made by work of a more urgent nature, there is little progress to report upon these investigations, which were described in detail in last year's report. The following are, however, nearly completed: Study of internal transverse fissures in rails; the heating stresses in car wheels; the distribution of temperature in cooling rails; the decomposition of cementite in cast iron by annealing, and the investigation of ingot practice, including chemical and metallographic surveys of several ingots, blooms and rails made by various processes. The installation of new apparatus and equipment will greatly facilitate the prosecution of this work.

The Failure of Brass.

Two important phases of this subject are still under investigation.

The thermal expansivities of pure beta and of pure alpha brass of composition found in heterogeneous alpha-beta brasses have been determined from room temperature up to 600° C., and a difference in these expansivities discovered sufficient, if fully effective, to produce moderately large initial stresses in a heterogeneous brass upon cooling rapidly from the upper temperature. The effect of such

stresses upon the tensile properties of 60 to 40 brasses was studied. The results of this investigation are embodied in Scientific Paper No. 321.

Twelve samples of drawn manganese bronze rod have been exposed for over a year while under tension, of known value, to corrosion by water. The results of these tests will determine the safe limits of stress allowable in this material when used for construction purposes such as bolts, and exposed to atmospheric or water corrosion.

These tests are being continued; more test frames are being built and naval brass will be added as a test material, and the effect of combined externally applied and initial stress will be studied.

Considerable work has been done in connection with brass cartridge cases submitted for metallographic examination by Ordnance Inspection Division and some manufacturers in testing out various solutions and in determining the effect of other conditions upon the indications of this test—size of sample, condition of surface, etc. In addition to the routine examination sufficient work was done to warrant embodying the results in printed form. This work should be continued when our rolling mill is in working shape and material of known preparation and physical properties can be readily obtained.

Acceleration Tests for Season Cracking and for Initial Stress.

With the aid of the new drawbench rods will be produced with varying amount and distribution of initial stress. These will be tested for both season and accelerated corrosion cracking (in mercury salt solution). The results will define the possibility of season cracking more definitely than heretofore both in terms of initial stress and of the results of the accelerated corrosion tests.

The Elimination of Initial Stress by Annealing.

The object of this investigation is to determine the temperature limit and periods of annealing necessary for the elimination of initial stress in different compositions of brasses. In rods of simple section initial stresses, producing season cracking, are most readily eliminated by the process of springing, such as by rolling in a straightening machine, but this method can not be applied to articles of irregular shape, stampings, etc., for which annealing may be necessary.

Arc Welding.

In cooperation with the Electric Welding Committee of the Emergency Fleet Corporation, an extensive program of investigation and tests of arc welds of ship plate has been undertaken. Besides usual tests which will be made by Division VII–1, special study will be made of the causes of brittleness in such welds and of the means for producing sound welds. This work is just beginning to get under way, and materials and welded specimens are being furnished by manufacturers.

Fusible Metals and Alloys.

The manufacture of fusible plugs.—This investigation is almost concluded. Some of the final conclusions are:

1. For casings material only bronzes of one of the following compositions should be used:

	I.	II.
Cu	88	87
Sn	10	7
Zn	2	5
Pb		1

2. Before pouring on the tin the casing should not be heated to over 300° C., while the casing should be tinned on the inside before pouring.

The effect of small amounts of impurities on the melting point of tin is now being studied. Antimony in small amounts, up to about 0.25 per cent lowers the melting point slightly, while quantities above 0.25 per cent raise the melting point considerably. The effect of copper, zinc, and lead is now being studied.

Aluminum Solders.

An investigation of a few commercial aluminum solders, and also some specially made up at the Bureau, has been completed. The results obtained are:

1. A soldered aluminum joint is rapidly attached when exposed to moisture, and is disintegrated due to the fact that the soldering alloys are all electronegative to aluminum.

2. Joints made by soldering should always be protected against this disintegration by either painting or varnishing, except in case of very heavy joints, such as repairs to castings, where corrosion at the joint surface would be of little consequence.

3. Solders should be applied without flux, and their composition may be varied within very wide limits. The two following general types are recommended:

	I	II
Zn.....per cent..	15–50	8–15.
Al.....per cent..		5–12.
Sn	Remainder	Remainder.

4. The higher the temperature at which the "tinning" is done the better the adhesion of tinned layer.

5. The joint between previously tinned surfaces may be made by ordinary methods, and with ordinary soft solder.

Tin Conservation.

All the tin used in the United States is imported, and there appearing a threatened shortage the Bureau has assisted the War Industries Board, after conferences and extended correspondence with manufacturers and consumers of articles containing tin, in making a program of limitation in its use and development of substitutes. The experimental work has followed the lines of finding suitable solders, reduction of tin in bearing metals, modifying bronzes, and recovering tin scrap. Suggestions to the Government departments concerning modification of specifications to conserve tin have also been made.

Cadmium Solders.

From the investigation as it has progressed so far it was found that cadmium solders of the following compositions:

	I	II	III	IV
Pb	90	80	85	75
Cd	10	10	10	10
Sn	.....	10	5	15

may be used to solder tin plate, terneplate, brass, and copper as the ordinary tin-lead soft solders. The manufacture and use of the 90–10 mixture is rather difficult, due to the extreme ease with which it oxidizes in the molten condition. The preferred composition is 80 per cent Pb, 10 per cent Cd, and 10 per cent Sn, and it has been tried out with success on roofing materials, tin cans, and tests on fire-extinguishers and automobile radiators are now in progress.

Bearing Metals.

Service tests of different compositions of bearing metals have been made with a view of determining the adaptability of certain lead-base babbitts hardened with alkali or alkali-earth metals. It was found that in some respects they were superior to genuine babbitt and their use is being recommended in certain cases.

The information assembled on this topic and the few tests which have been made on special bearing metals indicate a need for a systematization of our ideas concerning bearing metals in general, the advantages and disadvantages of different types, as well as some more extended study of the behavior of different compositions of both babbitts and bronzes in service. A circular is in preparation dealing with bearing metals, and upon its completion a program of bearing metal investigation will be mapped out.

Metals at High Temperatures.

It is hoped to be able to carry out experiments on interrelations of stresses and strains and the phenomena of annealing and hardening including effects of sizes and geometrical shapes, as well as more thoroughly quantitative studies of mass as related to heating and cooling rates.

Another problem to be taken up is that of the tensile properties of metals at high temperatures.

The constantly increasing use of metals and alloys at elevated temperatures, such as in turbine blades, pistons, etc., demands a thorough investigation into the physical properties at higher temperatures. Particularly a knowledge of the stresses which will be borne by metals and alloys at these temperatures without yielding is desired on every hand.

Apparatus has been designed for this work, which it is hoped, will be continued in the near future.

In a study of the heat treatment of various high-alloy steels, it is hoped to determine more completely the relations among the alloys in their effect on iron alone, and to proceed from that to the steels.

In the quenching of steels, quenching data in the literature refer to "quenching in oil," "in hot water," etc. It is proposed to put all such treatment in a standardized basis, e. g., "a cooling rate of 93° C. per second through the transformation range," etc., such data being obtained by use of the Einthoven galvanometer. Studies of grain size, hardness, and difference between inside and outside of specimen will be included.

The quenching speeds of various quenching media are also to be studied, to add to the somewhat meager data now available. The conditions which make for deformation of long, slender rods in quenching will also be studied.

Copper Plugs for Testing Cartridge Powders.

At the request of one of the powder companies the preparation, manufacture, and testing of copper plugs for control of cartridge powders is being planned. It appears that the uniformity of these plugs is very uncertain and the standard variable. It is probable that greater attention will have to be paid to grain size, conditions of annealing, freedom from oxide, and other factors.

Metals for Instrument Parts.

A study is being inaugurated of the composition and thermal treatment of metals suitable for certain aeronautical instruments, such as recording barometers, altimeters, etc., with the object of diminishing the elastic aftereffects which are usually so troublesome.

Preparation of Metal Specifications.

In addition to the specification work of the American Society for Testing Materials and of the International Aircraft Standards Board, the Metallurgical Division has assisted the several Army and Navy technical bureaus and the British Imperial Munitions Board in drawing up metal specifications, and a great deal of testing and experimental research has been carried out in connection with defining and fulfilling specifications. This work has necessitated innumerable conferences with military officers and has been undoubtedly one of the most useful phases of this year's work, as it certainly is one of the most far-reaching.

From our experience the past year it would seem wise to endeavor to establish a single board for metal specifications for specifications for the Army, on which the Bureau of Standards should be represented; there is at present considerable duplication of effort and confusion and some of the military departments need the advice and experimental facilities the Bureau of Standards can offer.

A very complete set of American metal specifications was furnished the French War Ministry's Committee on Metallurgical Standards.

METALLURGICAL CHEMISTRY.

(Preparation of metals and alloys from their ores; development of analytical methods for iron and steel; and preparation of pure metals.)

Electrolytic Carbon Method.

The method as outlined in last year's report has been further improved and simplified. A special procedure for determining electrolytic resistances has been developed, in which use is made of commercial 25 or 60 cycle alternating current in connection with the

Weibel galvanometer as a zero instrument. This method has proved much more satisfactory and is much simpler than the high frequency alternating current generator and telephone as zero instrument formerly used. A simplified gas absorption vessel with an adjustable cell constant replaces the fragile absorption apparatus used last year; this has the advantage over the latter of robustness and of being easier to build and easier to keep in working order. An improved chart for reading carbon percentage from the observed resistance and temperature has been devised. This replaces cumbersome tables and series of curves previously used for this purpose, and at the same time is more accurate. It is believed that this apparatus is now in its final form, and a set of 6 outfits for commercial use is being built. By this method an accurate determination of carbon in steel can now be made in $4\frac{1}{2}$ minutes.

Rapid Determination of Carbon in Steel by the Barium Carbonate Titration Method.

Means for increasing by 50 per cent the output of work when using this method are described in a paper in the Journal of Industrial & Engineering Chemistry. This paper describes the investigations made at the Bureau for increasing the speed of this method without much sacrifice in accuracy.

Nitrogen in Steel.

Several experimental forms of apparatus for the absorption of the nitrogen of this method have been built and tried. The most promising form is a steel test tube cooled by water jacket at the top and heated by an electric furnace to 800° to 900°. This tube incloses a hard glass test tube which contains a calcium inclosed in another iron tube. The space between the scale and glass tubes is evacuated to 20 to 30 millimeters before heating, and the collapsing of the glass tube is thus prevented; the glass tube is evacuated to 0.01 to 0.001 millimeter before heating. This apparatus is joined to the gas burette containing the nitrogen and to a McLoed gauge and the absorption of the gas followed by change of pressure. One hard glass tube serves for many determinations.

Goeren's Method for Determining Gases in Steels.

An electric vacuum furnace for this work, with carbon resistor and having special features, is now about complete in the shop. A satisfactory new form of sample-collecting mercury pump has also been built and fully tested. The pump originally intended for this work has undergone several modifications in the glass-blowing shop, and it is hoped that this will now be satisfactory. Several practical applications of this method of determining gases in steels are indicated by recent metallurgical problems brought to the Bureau by military departments of the Government and by commercial firms, and it is expected that much progress will be made in these studies during the coming year.

Determination of Gases by the Goutal Method.

Before completing the intended paper on this subject announced in last year's report, it was thought advisable to check some of the results previously obtained, using specially prepared reagents and

extra precautions. The results of this additional work fully confirmed the earlier conclusions.

Critical Study of the Ledebur Method for Determining Oxygen in Steel.

In this case, also, it was thought desirable before publishing the paper to make some searching investigation of certain sources of error, which work required several weeks. The work is now considered complete and the paper is in the hands of the Bureau Editorial Committee.

Oxygen Content (by the Ledebur Method) of Steels Deoxidized in Various Ways.

The work referred to in last year's report has been completed as to oxygen determination, and physical tests of this steel so prepared are about to be made. The chemical work indicates that the various methods of deoxidation used—namely, ferromanganese, ferrosilicon, aluminum, and titanium—have yielded steels with oxygen contents nearly identical, as shown by the Ledebur method.

Equilibrium Between Iron Oxide, Carbon, and Hydrogen.

The work on the Ledebur method, already referred to, made necessary an investigation of certain questions connected with this equilibrium. This work has now been completed and a paper describing it is being prepared. As a result of this investigation it is shown that carbon alone (as iron carbide in this case) reduces ferrous oxide at 800° to 900°, with formation of carbon monoxide and dioxide; as soon as hydrogen is introduced there is a partition of the reducing action between the hydrogen and carbide and the proportions of the reduction products (carbon dioxide, carbon monoxide, and water vapor) formed vary with the rate of passage of the hydrogen. With very low rates not more than 20 per cent of the iron oxide is reduced by that gas; a rate of not less than 4 liters per hour is necessary to effect a 90 per cent reduction by hydrogen alone. This investigation showed among other things, that the rate of hydrogen passing in the Ledebur method should not be less than 40 liters per hour.

Determination of Carbon Monoxide as Obtained from Steels.

Carbon monoxide is an important constituent of the gases extracted from steel when this metal is melted in vacuo. Certain hydrocarbons, produced by secondary reaction, are also present in these gases. Consequently, in order to determine carbon monoxide in such mixtures it is desirable to find a combustion method which will burn the carbon monoxide without affecting the hydrocarbons present. Tests have been made of a method using copper oxide at 250° as oxidizing agent, and it has been shown that fractional combustion of carbon monoxide is successfully effected in this way, provided unsaturated hydrocarbons are absent. Absorbents for the latter are now being investigated and it is believed that suitable ones have been found. A special form of electric furnace for heating several copper oxide reaction tubes in series has been designed and used for this work.

Special Alloy Work.

The apparatus for producing electrolytic iron and melting it in vacuo has been moved to the new chemistry building where it has been installed with improvements and additions and is now produc-

ing. The vacuum furnace for producing large ingots has been improved until it is now satisfactory. Difficulty was experienced in making crucibles of the tall narrow form wanted for melting pure iron-carbon alloys, this being due to the fact that no clay or other binder containing silica could be used for bonding the pure magnesia, on account of the contamination by silicon of melts made in crucibles so bonded. This difficulty was not met in our previous work where smaller quantities of iron were melted. Magnesia, unfortunately, has little strength of high temperatures, so that a bond of some kind is necessary. Our investigations have shown that alumina can probably be used successfully as a binder and careful analyses have thus far shown no contamination of the melts by reduced aluminum. Crucibles are either molded under pressure and placed in supporting crucibles of Acheson graphite or a lining of the magnesia-alumina material is rammed into an Acheson graphite crucible. Several large vacuum melting ingots have been produced. The present procedure for making such ingots, devised during the past few months, consists in melting in a gas-fired furnace the electrolytic iron mixed with enough pure carbon to saturate it (in order to secure a low melting point alloy). The crucibles used for this work are commercial plumbago crucibles protected by a rammed-in liner of pure Acheson graphite powder bonded with glucose. The iron-carbon alloys so produced are melted in the vacuum furnace, together with enough pure iron and iron oxide to lower the carbon content to whatever is desired.

Some method of premelting the electrolytic iron before melting in the vacuum furnace, such as that just described, is very desirable, since not enough of the unmelted electrolytic iron can be introduced at one filling of the vacuum furnace to make an ingot of the size wanted, and the vacuum furnace can not be opened for refilling until it is cool, which is wasteful of time and current.

As soon as a sufficient number of iron-carbon and pure iron ingots are produced these will be used as starting materials for the manganese-iron-sulphur carbon investigations described under the section of this report: "Manganese and Deoxidation Researches."

Improvements in the Bureau's methods of making pure magnesia with a view to substituting the now very expensive acetic acid are being investigated with some promise of success.

Pure Aluminum.

Researches at the Bureau of a military character have shown the possibility of obtaining remarkable properties in the metal and its alloys by the use of aluminum purer than that commercially supplied. Accordingly, special apparatus has been devised and materials have been assembled at the Bureau for carrying on an investigation with this end in view. The apparatus for electrolysis consists of a steel crucible lined with a pure Acheson graphite liner for holding the electrolyte and a gas furnace for keeping the contents of the crucible molten. A movable Acheson graphite rod set axially in the crucible serves as anode, and the crucible is arranged so the aluminum can be tapped off as desired. As soon as some uncompleted shop work is done the preparation of aluminum will be begun.

Plans have been devised for making still purer alumina if this is found to be desirable.

Manganese and Deoxidation Researches.

The proposition for an investigation of the use of manganese and other agents for the deoxidation of steel, with a view to conservation or substitution of manganese, with proposition originated in this Bureau as being very desirable from a military point of view, has been much extended. The Bureau of Mines and the National Research Council are now cooperating on this problem and the cooperation of other agencies is being enlisted.

As has already been emphasized in special reports on this subject, manganese is an essential element in present processes of making steel and the domestic supply of manganese ores is so inadequate that there is serious dependence on foreign sources, which is dangerous in war times. Hence, conservation of, and substitutes for, this metal are highly desirable.

Oil-Proofing Concrete Liners.

At the request of the Emergency Fleet Corporation work has been started with a view to finding means for rendering concrete ships impervious to light mineral oils. The methods suggested consist in covering with lead sheets, cast lead, sprayed lead, shellac, neat cement shot from a gun, barium sulphate, sodium silicate. Experimental investigations are being started on what seem to be promising lines.

FOUNDRY.

(Experimental and practical castings of metals, including special alloys for research and specialized purposes and practical foundry research.)

Foundry Investigations and Tests.

The investigation of casting methods and types of test bars as carried out by five foundries in an identical program and using metal cast in one heat has been completed and the physical properties of the brass determined. The metals used were Government bronze (88 Cu, 10 Sn, 2 Zn) and a modification containing 88 Cu, 8 Sn, 4 Zn. The results are ready for publication.

The effect on the physical properties of small additions of various metals to Government bronze is being studied systematically, and similarly for addition to aluminum. Special alloys suitable for castings are also made and examined as requested.

The type of test bar for different nonferrous alloys is being investigated.

The foundry serves the Bureau and the research laboratories of other departments and Washington institutions in preparing a great variety of kinds and types of metal and alloy castings. The new quarters have greatly extended its possibilities for service and research.

Sand Investigations.

This question has been taken up anew with regard to (1) reclaiming "burnt" steel foundry sand, (2) the production of artificial sands and establishment of standards, and (3) development of tests of sand qualities. The first has already given promise of demonstrating to

some foundries the reclaiming of 90 per cent of the sand at a reasonable cost. The Washington Navy Yard foundry and others are cooperating in this work.

Experimental and Practical Casting.

The foundry has made the following castings for experimental and special technical uses.

Metal.	Castings.	Patterns.	Weight
			Kg.
Aluminum alloy	255	76	138.63
Brass	241	84	420.75
Bronze	1,701	334	1,244.50
Cu-Mn-Ni alloy	1	1	12.00
Copper	6	4	132.00
Lead	10	5	33.70
Silver alloy	1	1	6.66
Tin	21	3	39.50
Zinc	13	8	424.53
Total	2,249	516	2,452.27

9. CERAMICS.

[Development of new uses for clays; replacement of imported by native materials; improvement of quality of products; designing and conducting tests for quality; standards of quality; routine tests for Government purchases; acting in advisory capacity as to conservation of fuel and transportation for ceramics; acting as clearing house for collection and dissemination of information.]

CLAY PRODUCTS.

(Investigation of building tile, and other clay products; industrial and educational cooperation; design of new equipment; development of enamels for iron and copper; studies of kiln efficiency; new uses for clay products; improvement of quality of products; manufacture of certain porcelains for Government use.)

Investigation of Building Tile.

The report covering the investigation of building tile is in the hands of Publication Committee. This report presents the results of compression and absorption tests on several hundred hollow building tile. The strengths in compression varied from 4,000 to over 10,000 pounds per square inch of net section of tile when tested on end, and approximately from one-half to three-fourths of these amounts when tested on edge or flat.

The tile absorbed from 4 to 11 per cent of water. The relative absorption power of a tile gives a fair indication of its strength, a vitrified tile absorbing least water, being hardest, and carrying the greatest compression load.

Industrial Cooperation and Dissemination of Technical Information Concerning Ceramic Products.

Cooperation is being maintained by the Bureau with many concerns and individuals with reference to industrial problems, both by correspondence and consultation. The volume of this work is constantly growing larger. Extensive cooperation is being conducted also with a number of technical organizations, such as the National

Brick Manufacturers' Association, the National Hollow Tile Manufacturers' Association, the National Terra Cotta Society, the Refractories Manufacturers' Association, the United States Potters' Association, the American Society for Testing Materials, the American Ceramic Society, etc.

Design of New Equipment.

All of the drawings for the new kilns, furnaces, and machinery to be erected in the new ceramic laboratory now under construction at Washington have been practically completed.

Enamels for Copper.

Work has been begun on enamels for copper as applied to dials to watches, scientific instruments, etc., for the purpose of displacing the enamels formerly imported from Germany.

Iron Enamels.

Two papers have been completed dealing with the subject of vitreous enamels applied to cast iron and steel. Since the literature dealing with this important industry is exceedingly meager, these contributions, which are voluminous and partake of the character of textbooks, should prove of considerable value to manufacturers and others interested in enameling.

Efficiency Studies of Ceramic Kilns.

A paper has been completed dealing with the study of the heat losses determined on a tunnel kiln and a down-draft kiln fired with producer gas.

The Use of Clay in Chemical Reactions.

Advice as to the best methods for selecting clays especially active in promoting certain gas reactions has been submitted to military authorities at their request.

Clay Aggregate for Concrete.

Work has been done in the production of a hard-burned but light clay aggregate for concrete for a special purpose with very satisfactory results, resulting in a concrete which is strong though of low lump specific gravity. Similarly, sand from crushed hard-fired clays was found to give good results.

Cooperation with the War Industries Board.

The services of the Ceramic Division have been called upon by the board upon the questions of replacing clays formerly imported from Europe, the proposed embargo upon English kaolins and ball clays, and the most economical distribution of refractories from the iron, steel, and coke industries.

Cooperation with the United States Fuel Administration.

Assistance is being rendered the Industrial Furnace Section in connection with a campaign aiming to bring about greater fuel efficiency in the firing of ceramic kilns, glass furnaces, etc.

Cooperation with the United States Potters' Association.

The Bureau has arranged with this association for an extensive study of possible combinations for white-ware pottery, using American clays exclusively. This work is to be done at 11 potteries in East Liverpool, Ohio.

Clay Survey.

Standardized tests of clays have been worked out for use in the general survey of the kaolin and clay resources of the United States, conducted by cooperation with the National Research Council, the United States Geological Survey, the Bureau of Mines, the Association of State Geologists, different State surveys, and the ceramic schools.

Pottery Saggers.

In the manufacture of pottery the breakage of the refractory containers (saggers) used to protect the ware during burning is a heavy item of expense. This is still more true in the manufacture of hard fire porcelain. By improving the quality of these refractories the manufacturing losses can be decreased very greatly. Work has been done in this connection, and the load carrying capacity of the saggers improved decidedly. These studies are being continued with reference to containers for special hard fire products like spark plugs, grinding wheels, etc.

Refractories for Marine Boilers.

A new type of refractory combining the qualities of porosity, light weight, and high refractoriness has been worked out and the results submitted to the Navy.

Work on Refractories.

The work done in the past justified an attempt to prepare general specifications for clay fire brick. As a result this was done and the proposed requirements for four classes of refractories submitted to the Refractories Manufacturers' Association, the Mellon Institute at Pittsburgh, and others for criticism. Checkwork done at the Mellon Institute has shown the specifications to be fair and reasonable.

Specifications for silica refractories are likewise being prepared.

A technologic paper on the subject of the sizing of calcined clay (grog) used in the building of refractory bodies has been published. It was shown that the density and strength of fire-clay materials hinge to a considerable degree upon the proper combination of sizes of grain.

Another technologic paper dealing with the structure and the manufacture of silica refractories is being printed. Similarly, a paper giving the results of tests upon 60 brands of American fire brick has been completed.

Refractory Porcelain.

Continued progress has been made in the development of refractory porcelain, formerly obtained from Germany, and the technique has been perfected so that it has been possible to make pyrometer tubes over 7 feet long.

Spark Plugs for Airplanes.

In cooperation with the Washington laboratory of the Bureau of Standards an extensive research was undertaken for the purpose of producing a porcelain-like body which shows a high electrical resistance at temperatures up to 600° C. and at the same time good mechanical strength when subjected to shocks and sudden heating and cooling. Such a body has been produced and is now being worked commercially. It has been shown in this work that the presence of feldspar is particularly injurious to the development of high electric resistance at the temperatures to which spark plugs are carried. This mineral constituent has therefore been eliminated. At the same time, the content of sillimanite in the finished porcelain has been greatly increased by the use of suitable calcines.

Crucible Clays.

Additional work has been done in the study of suitable clays by making up several sets of crucibles from different mixtures of typical clays and graphite. The most promising compositions resulted in a life of the crucible yielding from 25 to 30 melts.

Architectural Terra Cotta.

A large majority of the manufacturers of this decorative building material have submitted samples of their product to the Bureau for the purpose of determining the general physical properties. These samples were in the form of a specially made open box and also in the form of pieces left over from structures built by the manufacturers. There were thus obtained for testing, pieces especially made for testing purpose and pieces made in the ordinary course of manufacture. These were tested for strength in compression and their ability to withstand both natural and artificial freezing (produced by the crystallization of sodium sulphate). In addition the absorption at various periods was determined.

While in general the results show that increased strength is accompanied by decreasing absorption and increasing ability to withstand freezing, yet there were such exceptions to the statement that further work is necessary, especially in investigating the burning of the clays used. It was gratifying to find, by the compression tests, that practically all the pieces were able to withstand stresses greater than those which would be imposed upon them in structures. It was also found that test pieces specially burned for testing purposes, do not frequently give a true indication of the properties of the material burned as a piece for structural purposes.

Hard-Fire Porcelain.

The study of this subject has been prosecuted vigorously and a large amount of data has been obtained. Over 120 porcelain compositions have been made and tested. It has been found possible to fix the limits of composition for the several types of porcelain and to demonstrate the effect of the reducing or oxidizing conditions during firing. Particular attention has been paid to the subject of chemical porcelain and a new type of body produced which possesses valuable properties. Cooperative work in this connection has been done

with two manufacturing concerns. In one case it was found possible to improve the quality of the product decidedly as well as to increase the yield of the first-class ware.

Particular attention has been given to the development of a true hard-fire porcelain from American materials and assistance has been rendered prospective manufacturers to make the new industry possible. One pottery of this type is already in course of construction and the new development should result in the elimination of such porcelain imported formerly from Austria and Germany.

GLASS.

(Examination of raw materials for glass and for glass pots; development of improved methods for making glass pots; design of plant for manufacture of glass pots on large scale; manufacture of a particular quality of optical glass on large scale for Government use.)

Examination of Raw Materials for Optical Glass Manufacture.

A large number of samples of sand, potash, soda ash, limestone, lead oxide, barium carbonate have been analyzed with reference to their content of impurities which are objectionable for the production of fine optical glass.

Casting Process.

Owing to the desirability of replacing expensive hand processes by quicker methods the question of making glass pots, crucibles, etc., by pouring the liquid mass into plaster molds was taken up and solved successfully. Owing to the heavy and massive articles thus to be made special mold constructions and means of handling had to be worked out. A plant for casting heavy ware was erected which is capable of producing 2 to 3 glass pots per day. The economic phases of the process were studied in detail and drawings prepared showing the arrangement of machinery and accessory apparatus, together with a description of the manipulations involved. This information has been given to 5 producers of glass pots, and is available to any concern which is interested.

Glass Pots.

One of the fundamental problems connected with the production of optical glass is the use of pots resistant to the corrosive action of these glasses and very low in iron content. For this reason the clay products laboratory has devoted considerable attention to this work with the result that a very satisfactory composition of the nature of porcelain has been worked out, which resists even the violent corroding action of the heavy barium glasses. Since the commercial pots are entirely unsuited for this purpose, instructions concerning the composition and making of the porcelain pots thus developed have been imparted to 5 commercial concerns, of which 3 are now producing them. These data have been published also in articles appearing in Metallurgical and Chemical Engineering and the Journal of the American Ceramic Society.

It has been found possible also to reduce the cost of the porcelain pots by making use of the bisque waste from white ware potteries, which formerly was thrown away or sold at a negligible figure. Since this material makes up practically one-half of the composition the cost of the white glass pots is about the same as that of the ordinary ones. The porcelain pots are being made at the Pittsburgh laboratory both by the usual hand molding and the casting methods.

The porcelain composition is being used also for the stirring rods required to mix the fused glass.

Optical Glass.

The optical glass laboratory erected during the summer of 1917 is now in operation and during the year 200 melts have been made in large pots. Eight gas-fired furnaces are in operation, with the necessary complement of heating, softening down, and annealing furnaces. About 5 melts of glass are being made per week. The processes of manufacturing optical glass have been mastered in practically every detail and 7 types of optical glass have already been made varying in index of refraction from the lowest to the highest values.

The problem of surfacing glass has also been studied and a set of machines for grinding and polishing has been installed. Much study has been given to the problem of rapid though rigid inspection and apparatus installed at the Pittsburgh laboratory, at the plant of the Pitsburgh Plate Glass Co., and of the National Optical Glass Co., at Washington, Pa. The Bureau of Standards laboratory advocates inspection through the edges of the glass plates as being more rigid and detecting imperfections, such as striæ, which readily escape observation when the glass is examined flatwise.

The Pittsburgh glass laboratory ships monthly more than a ton and a half of rigidly inspected glass. For the purpose of utilizing small pieces of good glass a press has been set up for making the blanks of small lenses. Additional presses for making prisms and other blanks are about to be installed. In addition to the productive work, researches in connection with improvements in the manufacture of optical glass are being conducted constantly and the mass of information thus accumulating is certain to be of great value in establishing all the details of production on a firm basis, a condition which will assist in making this country independent of any German supply of optical glass.

Cooperative work was conducted with 3 commercial plants with reference to the production of optical glass and with 6 factories in connection with manufacturing problems relating to staple articles.

Work has also been done on special colored glasses for special applications and on the problem of producing glass for artificial eyes, all of which has been successful.

All plans and designs for the new glass laboratory now being built on the grounds on the Bureau of Standards at Washington have been completed and the contracts signed.

LIME, GYPSUM, ETC.

(Investigation of proper quality of lime for different chemical industries; development of standard specifications for lime and gypsum as building materials; laboratory and technical work to determine the qualities of the product; development of methods of testing for plasticity, sand-carrying capacity, soundness, etc.; routine tests of material purchased by the Government; consultation as to the availability of different qualities of material at the markets and for the purpose specified; determination of the value of an addition of hydrated lime to concrete.)

The Use of Hydrated Lime in Concrete.

The use of hydrated lime as one of the ingredients of Portland cement concrete has been rapidly increasing during the past few years. From observations made under working conditions some engineers and contractors make the following claims as to the benefits derived through this practice: Concrete containing hydrated lime requires less water for mixing, is more plastic, separates into gravel and mortar less readily, flows down chutes and into forms more readily, is stronger, denser, and more impermeable to water than concrete not containing hydrated lime.

Since very little experimental work had been done for the purpose of determining the validity of these claims, it was decided to conduct an extensive investigation with this object in view.

Laboratory work in this investigation has been in progress for two years. The following physical properties of concrete have been studied: Compressive strength, bond strength with steel, expansion and contraction with time, amount of water absorption, density of the fresh concrete, modulus of elasticity.

The results have not been completely analyzed on account of the difficulty of choosing the proper basis for comparison. On this account the general tendencies noted in the annual report for 1917 were inaccurate in degree and the statements therein given are to be modified to agree with the present understanding of the effect of different factors upon properties of concrete. At the present time the most comprehensive and logical basis of comparison seems to be a factor known as the water-ratio. This factor, which bears a mathematical relation to compressive strength, is found by dividing the volume of water by the volume of cement used in the concrete. Using this factor as a basis the results show that concrete containing hydrated lime is on the average stronger than concrete without lime, the increase in strength being the more pronounced in air storage specimens and in concretes having the higher water-ratios. Results for the other properties mentioned have not yet been compiled for comparison in this manner.

In regard to the remaining properties, it may, however, be said that the laboratory specimens having all been made with great care did not give so large a degree of difference in properties due to the introduction of hydrated lime as is claimed by contractors and engineers to occur under the conditions of construction work. Moreover, the laboratory results told nothing of the effect upon time of flow down chutes, plasticity, degree of segregation, etc.

For this reason it has been decided to conduct an extensive investigation under working conditions. Preliminary work will be conducted by use of an experimental concrete plant now erected. Following this, observations will be made at various large construction works.

Properties of Hydrated Limes.

The commercial product known as hydrated lime has been upon the market comparatively few years, and although it is manufactured by about 85 companies no complete determinations of its physical and chemical properties had been made. About all that has been known concerning this product is that it has replaced quicklime for a number of the purposes of construction.

During the past three years physical and chemical tests have been made upon 54 samples of hydrated lime collected from all parts of the country. The data affords a fairly complete knowledge of the properties of this product valuable alike to producer and consumer, enabling them to improve the quality and to write accurate specifications.

Plasticity of Hydrated Limes.

Lime manufacturers have become accustomed to use the term plastic lime as meaning a lime producing a paste when slaked and allowed to stand with water, this paste being capable of retaining its water long enough to be spread easily and smoothly upon an absorbent surface such as is provided by the brown coat wall plaster.

Under these conditions the rate of change of plasticity is more important than the absolute plasticity.

The Bureau has designed an instrument now known as the Emley plasticimeter for the purpose of measuring the relative rate of change in the forces acting between a paste and a trowel while the paste is drying out upon an absorbent surface.

By this means lime pastes have been classified into plastic and nonplastic pastes, using the manufacturers' definitions. About 25 hydrated limes from all parts of the country have been tested.

A mathematical definition of plasticity as applied to the use of lime was not obtained and until considerable more work has been done along this line, it will be necessary to use the trade definitions.

Sand-Lime Brick.

The sand-lime brick industry has been seriously hampered during the past year by inability to obtain lime and coal when needed. The principal technical problem at the present time is hence the saving of coal required to produce steam in the steaming process. On account of lack of help the Bureau has not yet been able to attack this problem.

Another important problem is the production of brick of better quality. This involves quality and proportions of the materials, methods of molding, and steaming. One phase of this problem has been attacked, namely, the effect of the size of grain of the sand upon compressive strength of the brick. Three sizes of sands were mixed in 63 different proportions. These sizes were 10 to 40 mesh, 40 to 100 mesh, and 100 to dust. The strongest brick were obtained with mixtures of 30 to 60 per cent 100-to-dust sand, 40 to 70 per cent 10 to 40 mesh sand, and 0 to 20 per cent of 40 to 100 mesh sand. The strongest specimens ($1\frac{1}{2}$-inch by $2\frac{1}{2}$-inch cylinders) had a compressive strength of 6,500 pounds per square inch.

Gypsum Products.

No extensive determinations have been made of the properties of gypsum products from mills in this country. There exist no standard specifications for these products.

In order to obtain the necessary knowledge it has been decided to conduct an extensive investigation upon gypsum products from various parts of the country. The preliminary work is now in progress and consists of heating a very pure gypsum to different temperatures and determining such properties as compressive and tensile strength, time of set, optical properties, etc.

The data obtained will afford first-hand knowledge of the quality of the products and enable the Bureau to cooperate with the organizations interested in drawing up standard specifications.

Dolomite as a Refractory.

In many metallurgical furnaces it is necessary to use brick which are chemically of a basic nature. Magnesite brick are so used at the present time but are very high in cost. There are large deposits of dolomite all over the country. If the proper flux could be found to bind and coat dolomite particles so as to prevent rapid hydration of the lime, a dolomite brick could be produced which would replace to a great extent the magnesite brick.

Some work was done along this line but it had to be discontinued on account of lack of help and was not carried out to a practical conclusion. A number of different compositions were used. The most promising composition will be described.

The brick was made of two parts, one of burned material known as grog which formed the skeleton of the brick, the other part of unburned material known as binder. The grog portion was made by burning to a temperature of 1500° C. a mixture of 90 per cent dolomitic hydrated lime and 10 per cent of a special flux, the mixture being ground to pass a 100-mesh sieve. The flux was produced by burning to a temperature of 1400° C. a mixture of equal weights of dolomitic hydrated lime and impure bauxite, ground to pass a 100-mesh sieve. The binder consisted of 85 per cent of the dolomitic hydrated lime and 15 per cent of the flux.

The brick were made by mixing thoroughly 70 per cent of the grog (of 6 to 40 mesh size) with 29 per cent of the binder and 1 per cent of iron oxide, and molding in a power press. The brick was dried in an oven at 110° C. and burned to a temperature of about 1500° C. and Seger cone 20.

The specimens molded with a pressure of 2,500 pounds per square inch appeared to be most satisfactory. Some of the specimens when placed in water resisted hydration for 6 days. Others when left in the open air in the laboratory remained very hard and did not begin to hydrate until they had stood for 6 months. These results would indicate that such a brick placed in a furnace would resist hydration and disintegration for a much longer time.

Hydrated lime was used because a large supply was on hand at the laboratory. For the grog portion and for the flux the hydrated lime could be replaced by ground dolomitic limestone. The binder must be a finely ground material which will not hydrate and cause disintegration in drying and burning. The possibilities for this purpose are hydrated lime, ground dolomitic limestone, ground slag, Portland cement.

The question of costs has not been gone into nor has any attempt been made at a practical application of the method, but the results indicate that the problem can be solved by sufficient experimental work.

III. THE OFFICE.

[Office management; finance and accounts; personnel actions and records; editorial work, printing, publicity; property and stores, including distribution and accounting; mail and files, including test records; scientific library; dispatch, including all forms of transportation and communication; purchasing; stenography, typewriting, and duplicating; and information service.]

The Office Division handles the general business of the Bureau. The aim is to leave the scientific divisions free for the scientific and technical work, although some dovetailing of functions is essential. The office is organized with 10 sections, with representative clerks assigned for the office work for each division. These sections are designated as follows: administrative, finance, personnel, publicity, property and stores, mail and files, library, dispatch, purchases, copying (detailed to division offices), information. Each section has a definite function, and it is the aim that each section shall handle all Bureau business which properly pertains to such function. This policy is equally true of the scientific sections and the sections of the mechanical plant.

The new policy of providing central office overhead allotment from all funds permitted prompt expansion and organization of the office work on a more efficient basis as called for by war conditions. The loss by military demands of nearly all clerks in the 10 sections of the office resulted in hardship and temporary ineffectiveness, which careful reorganization and improved methods have partially remedied. In several sections it is not yet possible to render the most effective service because of the inexperience of new clerks and the highly technical character of the subject matter of the Bureau's work. Rapid progress, however, has been made in bringing the office work to the new standard of efficiency demanded.

It is a pleasure to refer to the unstinted efforts of the entire office force to carry the expanded work under the trying war-time conditions of the past year. The spirit of service has been excellent with no trace of the spirit of mere timeserving. The gratifying work of the past year toward winning the war was made possible by the enthusiastic support of the entire office staff.

FINANCE.

[Records of appropriations and allotments; order and voucher accounts; balances; reimbursements; checking commercial, construction, and travel expense vouchers; pay rolls; test fees; fiscal statistics.]

During the year this section has handled accounts aggregating $3,414,345.50. In addition to 26 direct appropriations for the Bureau, $1,395,000 was assigned by the President to the Bureau from the National Security and Defense fund for the purpose of erecting war buildings to provide additional laboratory space needed

to meet the demands of war problems and for specific researches in connection with the war. Other departments of the Government allotted $218,000 to the Bureau to cover the cost of special cooperative war researches undertaken by the Bureau at their request. The erection of the emergency war buildings on a cost plus basis necessitated the checking by the Accounts Section of the material and labor entering into their construction. The personnel was increased to enable the section to care for the extra financial work involved.

A new card accounting system for handling accounts was devised early in the year and assisted greatly in expediting the accounting work.

A card system is being introduced for pay rolls in connection with the new clerk to be assigned to this work and will place this work on a more efficient basis.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1918, the disbursement during the year, the amount of unfilled and unpaid orders at the close of the year, and the unexpended balance remaining at the close of business June 30, 1918:

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
Salaries	$348,900.00	$303,420.27	$15,952.62	$29,527.11
Equipment	55,000.00	44,138.18	10,639.23	222.59
General expenses	35,000.00	27,000.00	6,136.54	1,544.88
Repairs and alterations	5,000.00	4,423.19	572.25	4.56
Grounds	6,000.00	4,763.11	1,232.13	4.76
High-potential investigation	15,000.00	11,189.45	3,810.55	.....
Testing structural materials	[a] 154,130.62	132,403.33	21,727.29	.....
Testing machines	30,000.00	22,674.05	7,240.85	85.10
Investigation of fire-resisting properties	25,000.00	22,255.75	2,731.68	12.57
Public-utility standards	50,000.00	45,904.19	4,095.81	.....
Investigation of railway materials	15,000.00	11,495.78	3,504.22	.....
Testing miscellaneous materials	20,000.00	19,120.86	879.14	.....
Radio research	10,000.00	8,495.41	1,474.33	30,26
Color standardization	10,000.00	8,358.54	1,631.43	10.03
Investigation of clay products	10,000.00	9,994.53	3.00	2.47
Physical constants	5,000.00	4,737.32	251.53	11.15
Standardizing mechanical appliances	10,000.00	9,510.66	139.49	349.85
Investigation of optical glass	10,000.00	9,002.37	958.90	38.73
Testing railroad scales	40,000.00	28,557.71	11,442.29	.....
Additional land	25,000.00	.....	.....	25,000.00
Radio laboratory	90,000.00	58,096.28	23,569.37	8,334.35
Chemical laboratory	200,000.00	197,236.48	319.55	2,443.97
Military research, 1917-1918	[b] 577,176.88	361,512.41	215,664.47	.....
Gage standardization	[c] 226,138.00	141,604.47	84,533.53	.....
Equipping chemical laboratory	35,000.00	24,558.89	10,440.84	.27
Repairs, power plant	12,000.00	.....	11,870.00	130.00
NATIONAL SECURITY AND DEFENSE.				
Production of optical glass	75,000.00	74,539.86	460.14	.....
New building	250,000.00	232,552.39	17,447.61	.....
Metallurgical work	100,000.00	40,579.65	59,420.35	.....
Production of fabrics	35,000.00	326.75	34,673.25	.....
Industrial laboratory	925,000.00	257,360.76	415,547.71	252,091.53
Roberts' coke oven	5,000.00	1,929.15	2,993.60	77.25
Thermite investigation	5,000.00	7.00	699.39	4,293.61
Total	3,414,345.50	2,118,067.37	972,063.09	324,215.04

[a] Includes reimbursement of $4,130.62.
[b] Includes reimbursement of $109,176.88 and allotments from War Department to amount of $218,000.
[c] Includes reimbursement of $1,138.

The following statement shows the condition of the appropriation for the two preceding fiscal years at the close of business June 30, 1918:

FISCAL YEAR 1916.

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
Salaries	$298,780.00	$283,079.84	.....	$15,700.16
Equipment	50,000.00	48,175.29	$406.43	1,418.28
General expenses	27,000.00	26,645.24	245.55	109.21
Repairs and alterations	2,000.00	1,977.78	8.10	14.12
Grounds	6,000.00	5,901.11	.....	98.89
High-potential investigation	15,000.00	14,908.67	43.25	48.08
Refrigeration constants	15,000.00	14,923.23	.....	76.77
Testing structural materials	100,000.00	99,437.16	127.53	435.31
Testing machines	30,000.00	29,899.16	.....	100.84
Investigation of fire-resisting properties	25,000.00	24,888.12	59.00	52.88
Public-utility standards	25,000.00	24,800.99	.....	199.01
Railway materials	15,000.00	14,514.15	175.51	310.34
Testing miscellaneous materials	20,000.00	19,999.96	.....	.04
Current-meter testing tank	3,000.00	2,998.34	.....	1.66
Heating system, north laboratory	3,000.00	2,520.54	.....	479.46
Radio research	[a] 12,308.74	12,141.49	.....	167.25
Testing railroad scales, etc	40,000.00	27,751.80	12,248.20	.....
Total	687,088.74	654,562.87	13,313.57	19,212.30

[a] Includes reimbursement of $2,308.74.

FISCAL YEAR 1917.

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
Salaries	$311,720.00	$289,777.80	.....	$21,942.20
Equipment	50,000.00	46,180.70	$3,819.30	.....
General expenses	28,500.00	27,382.62	878.35	239.03
Repairs and alterations	5,000.00	2,612.44	2,153.80	233.76
Grounds	6,000.00	5,449.30	497.37	53.33
High-potential investigation	15,000.00	14,876.43	10.16	113.45
Refrigeration constants	15,000.00	14,942.26	15.00	42.71
Testing structural materials	100,000.00	98,634.74	635.84	729.44
Testing machines	30,000.00	29,536.44	209.22	254.32
Investigation of fire-resisting properties	25,000.00	24,921.59	.....	78.44
Public-utility standards	40,000.00	39,627.27	103.92	268.81
Railway materials	15,000.00	14,763.43	185.40	51.11
Testing miscellaneous materials	20,000.00	19,903.38	.....	96.67
Radio research	[a] 15,359.71	10,460.69	4,173.25	725.72
Color standardization	10,000.00	8,899.35	992.10	108.57
Clay products	10,000.00	9,973.39	.....	26.61
Physical constants	5,000.00	4,369.12	153.86	477.02
Standardizing mechanical appliances	10,000.00	9,410.64	416.07	173.29
Testing railroad scales, etc	40,000.00	35,599.63	4,400.37	.....
Total	751,579.71	707,321.22	18,644.01	25,614.48

[a] Includes reimbursement for $5,359.71.

Summary of Tests.

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. It involves primarily the investigation of the scientific principles underlying the tests, the studying of existing methods, and the development of new standard tests of determinate accuracy. For each test a reasonable fee is charged, except when made for the National or State Governments.

During the fiscal year 1918 the Bureau made 312,563 tests and inspected 3,727,352 incandescent lamps at various factories for other departments of the Government. Of the total tests, 31,571 were for

the Government and 280,992 for the public. The testing was distributed as follows, according to the nature of the tests: Length measures, 1,064; mass, 1,815; capacity, 504; temperature, 282,094; hydrometry, 2,088; miscellaneous, 30; optical, 2,126; time, 2,064; electrical, 1,910; photometry, 4,874; chemical, 4,589; engineering (miscellaneous), 740; engineering (instruments), 202; structural materials, 3,423; paper and textiles, 4,618; metallurgical, 34; aeronautical instruments, 388. The estimated fees amount to $102,878.63, of which $16,626.97 was collected on account of tests for the public. The fees noted for Government tests are included merely for comparison purposes, as no charge is made for tests performed for the National or State Governments.

Number and value of tests completed, fiscal year ending June 30, 1918.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length	790	$1,013.35	274	$420.75	1,064	$1,434.10
Mass	661	606.20	1,154	555.20	1,815	1,161.40
Capacity	363	354.00	141	163.70	504	517.70
Optical	2,069	3,131.70	57	289.50	2,126	3,421.20
Hydrometry	1,440	1,348.70	648	855.10	2,088	2,203.80
Miscellaneous	16	36.50	14	25.50	30	62.00
Time	2,062	217.70	2	7.00	2,064	224.70
Temperature	8,021	1,874.78	274,073	3,014.00	282,094	4,888.78
Electrical	1,344	4,611.55	566	2,937.47	1,910	7,549.02
Photometry [a]	4,750	19,174.70	124	255.00	4,874	19,429.70
Chemical [b]	901	4,463.23	3,688	7,232.85	4,589	11,696.08
Physical and mechanical tests:						
Engineering, miscellaneous	723	2,335.00	17	18.00	740	2,353.00
Engineering instruments	165	886.00	37	196.00	202	1,082.00
Structural materials	3,363	28,174.25	60	184.90	3,423	28,359.15
Paper and textiles	4,489	15,777.00	129	391.50	4,618	16,168.50
Metallurgical	27	197.50	7	72.00	34	269.50
Aeronautical instruments	387	2,049.50	1	8.50	388	2,058.00
Total	31,571	86,251.66	280,992	16,626.97	312,563	102,878.63

[a] In addition the Bureau inspected 3,727,352 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $9,318.38.
[b] Of these tests, 2,407, amounting to $21,722.25, were chemical tests made on structural materials.

Statement showing the number and value of tests made for the Government and the public at the Pittsburgh laboratory of the Bureau of Standards during the fiscal year 1917–1918.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
CEMENT.						
Physical	2,507	$7,275.00	4	$18.00	2,531	$7,293.00
Chemical	404	1,424.00			404	1,424.00
CLAY PRODUCTS.[a]						
Physical	89	570.00	20	71.00	109	641.00
Chemical	6	65.00			6	65.00
MISCELLANEOUS.						
Physical	95	668.00	54	241.00	149	909.00
Chemical						

[a] In addition, preliminary tests, for which no fee is charged, were made on 52 samples of clay.

PERSONNEL.

[Organization charts of divisions, staff status, individual records of all employees, including military employees; personnel changes, directories, systems of examinations; records of leave, tardiness, delinquency, and efficiency; passes and credential cards, injury and first-aid records and reports, and records of employees who have entered military service.]

Personnel Changes.

During the fiscal year 1917–18 the Bureau staff comprised 278 statutory employees, and about 839 engaged in research and investigations especially authorized by Congress. The statutory positions included 170 scientific positions, 37 office assistants, 46 engaged in the operation of the plant, and 25 in the construction. In addition to the above there were 288 employees detailed from other Government departments or organizations for work in the Bureau, making a grand total of 1,405 employees. There were 2,955 personnel changes during the year, of which 757 were separations from the Bureau, 288 resignations, 568 promotions, and 1,533 appointments. The high labor turnover reflects the war conditions. The enterprise of the members of the personnel section has met the emergency with effectiveness.

Appointments.

	Number.	Total.
Competitive	433	
Excepted	10	
Unclassified	70	
Total permanent		513
Total temporary		1,070
Total appointments		1,583

Separations.

	Number.	Total.
From competitive positions	241	
From excepted positions	17	
From classified positions	30	
Total permanent		288
Total temporary		469
Total separations		757

Promotions and Other Changes.

	Number.	Total.
Promotions	586	
Reductions	8	
Miscellaneous changes	21	
Total personnel changes		2,955

Efficiency Methods.

The complexity of the personnel classes, the unusual technical qualifications required, the sudden demands for assistance in emergencies, and the high labor turnover are probably unique in a Federal bureau and have called for efficient planning of methods. New and effective methods were devised and put into operation to facilitate the work, with notable gain in promptness, economy, and efficiency. These include a series of routing slips covering each set routine, as automatic check against omission. Visible indexes were installed, forms and routine were standardized, a daily journal was adopted,

greatly economizing labor in making recommendations. Without these improvements in practically every detail of the work of the personnel section, the work could not have been carried. The results shown in this work during the past year have been gratifying.

PUBLICATION.

[Editorial work, routing of manuscripts and proof documents; archives, publication stock distribution, abstracts of publications.]

The necessity of having the results of the various investigations conducted by the Bureau, available for ready reference throughout the country, makes it imperative that these results be published in pamphlet or book form, in numbers sufficient to provide for widespread distribution.

The results of these investigations are published in pamphlet form, and in the following pages are given descriptive lists of these papers. The papers are issued in four separate series: (1) Scientific papers; (2) technologic papers; (3) circulars; and (4) miscellaneous publications. They cover a wide range of subjects in the field of physical measurements and the properties of materials and are issued for general distribution to the scientific, technical, and industrial interests concerned with the subjects treated. Single copies of these publications are sent upon request to scientists specializing in the subjects treated, to those collaborating with the Bureau in its investigations, to organizations exchanging like courtesies with the Bureau, and to depository libraries. Others, however, may purchase them from the Superintendent of Documents. It is assumed that individuals generally are interested in a particular class of work, hence this method of distribution has been adopted in order that each may secure readily the particular information desired.

Publication.

During the past fiscal year the Bureau issued 53 publications, of which 46 were new and 7 were revised editions. In addition, approximately 23 publications were reprinted, owing to the urgent demand for them. The new publications include 15 scientific papers, 16 technical papers, 11 circulars, and 3 numbers of the Bulletin of the Bureau of Standards.

Printing.

During the year 366 printing requisitions other than for publications were prepared. These are for the certificates for tests and the necessary administrative blanks and record books.

Distribution.

Under normal conditions the work of handling requests for publications is completed daily. The efficiency will unquestionably be increased when the adequate space is provided for the work of handling publication stocks. The need for a small stock at the Bureau is imperative, but the congested condition of the room has occasionally resulted in delays. The new plan for handling requests for publications has worked very satisfactorily.

New Publications.

During the fiscal year the following scientific papers were issued: A Method for Testing Current Transformers; Some Electrical Prop-

erties of Silver Sulphide; Axial Aberrations of Lenses; Wave Length Measurements in Spectra from 5600A to 9600A; Specific Heat of Liquid Ammonia; The Latent Heat of Pressure Variation of Liquid Ammonia; Latent Heat of Vaporization of Ammonia; Gas Interferometer Calibration; The Resonance and Ionization Potentials for Electrons in Cadmium Vapor; The Application of Dicyanin to Stellar Spectroscopy; Instruments and Methods of Radiometry, III; Selective Radiometry; Additions to the Formula for the Calculation of Mutual and Self-Inductance; Thermal Expansion of Alpha and Beta Brass; Photo-Electric Sensitivity of Various Substances; Some Characteristics of the Marvin Pyrheliometer.

The following new technological papers were issued: Crystalline Changes in Wrought Iron; Effects of Heat on Celluloid and Similar Materials; Gas Mantle Lighting Conditions in Ten Large Cities in the United States; Determination of Absolute Viscosity by Short Tube Viscosimeters; Investigation of Large Bridge Columns; Properties of Portland Cement Having a High Magnesia Content; Typical Cases of the Deterioration of Muntz Metal by Selective Corrosion; Effect of the Size of Grog in Fire Clay Bodies; Comparative Tests of Porcelain Laboratory Ware; Stabilized Platform Weighing Scale of Novel Design; Comparative Tests of Chemical Glassware; Ground Connections for Electrical Systems; Clay and Porcelain Pots for Optical Glass; The Influence of Quality of Gas and Other Factors Upon the Efficiency of Gas Mantle Lamps; Compressive Strength of Large Brick Piers; Standardization of the Saybolt Universal Viscosimeter.

The following new circulars were issued: Combined Table of Sizes in the Principal Wire Gages; Public Utility Service, Standards of Quality and Safety; Paint and Varnish; Materials for the Household; Rules and Regulations Promulgated under Authority of the Federal Standard Barrel Law; The Scope and Application of the National Electrical Safety Code; Copper; Radio Measurements and Instruments; Safety for the Household.

The Annual Report of the Director of the Bureau of Standards for the Fiscal Year ended June 30, 1917, is the only new miscellaneous publication issued during the year.

PROPERTY AND STORES.

[Property inspection, quantity and quality checking; accession, recording; accountability, charge and release; condemnation and disposal; stores, stock distribution and renewals.]

The office has prepared and issued to the responsible officers of the Bureau a standard stock catalogue listing in detail the items carried in stock in the storeroom. This catalogue contained the principal articles required for use in the offices and laboratories of the Bureau. The central stock room purchased and stored approximately $43,000 worth of material. This involved the handling of the approximately 19,200 items for the central storeroom. In addition, approximately $37,000 worth of standard stock was distributed to the laboratories, including 19,800 stores requisition and 104,000 items issued. During the last part of the year the work of the storeroom increased by about 40 per cent.

Equipment Records.

The work of accession and recording of inventoried equipment comprises the writing of 28,000 cards and 19,700 pieces of equipment. The growth of this work has in the past 6 months increased 50 per cent.

Progress.

A perpetual inventory method showing at a glance all items carried in stock and the quantities on hand has been initiated in the storeroom. Adequate housing for the overflow stock has been fitted up, but the rapid growth in this section will necessitate permanent provision of larger space.

PURCHASE.

[Trade catalogues and dealers' lists; requisition inspection; preparation of orders, bids and orders, order follow-up; purchase and transportation checking.]

The activities of this section increased 100 per cent during the past year, necessitating the reorganization of the office and the separation of this section from the storeroom and finance sections.

The rapid expansion of the Bureau's work during the year caused by the war resulted in a very large increase in the number of orders placed, 8,069 orders being the total number, 5,440 largely for technical materials and apparatus.

The Purchase Section maintains a file of scientific and industrial catalogues for consultation. The variety of technical equipment and supplies required calls for investigation which takes a considerable part of the time of those concerned. Records are kept of the purchases and quotations in such form that they may be readily consulted in future cases.

MAIL AND FILES.

[Handling of correspondence, including business and technical communications of all kinds; the accession, distribution, and filing of such papers; test records.]

No section in the Bureau has suffered a more complete loss of experienced and skilled assistants than the section of mail and files. The loss of the entire staff of 6 men, with the experience which they had acquired in their years of service, could not be made up promptly. The war caused a rapid increase in the work and it became necessary to route military mail to secure promptness on urgent cases and confidential handling on other cases, and systematic follow-up for all military matters. A new system of record and follow-up was devised and put into effect in the director's office, with marked increase in the efficiency of such work. The volume of correspondence increased very greatly and a new classification is now being installed.

LIBRARY.

[Maintenance of scientific and technical library; bibliography; accessioning new books; loan and accountability records; assistance to technical staff, and rebinding.]

The Bureau maintains a scientific library, containing 16,339 accessioned volumes. Three hundred and forty-two scientific and technical periodicals are currently received. This is an increase of 45 over the previous year. The number does not include 96 different journals which fail to reach the Bureau on account of the war. Of the latter, 74 are German journals.

Important Accessions.

The library has been fortunate in being able to secure a large number of missing numbers and volumes of important journals and to complete a number of the more important sets. This was not accomplished without the most careful scrutiny of the catalogues of second-hand works, published in America and Europe.

Equipment and Space.

While the library is in congested quarters, the equipment is modern and effective for its purpose. Additional space, however, is urgently called for in order that the centralization demanded by efficiency may be completed.

DISPATCH.

[Transportation and communication of all kinds, comprising telephone and telegraph service, express, freight and mail shipments, drayage, and messenger service.]

The work of this section has been somewhat divided, owing to the rapid growth of the Bureau and the failure thus far to fully centralize the dispatch service. Plans have been perfected for the consolidation, and it is expected that this will be accomplished in the very near future. The work of the section has expanded very greatly requiring now the service of five trucks and three automobiles. The fact that the work of the Bureau is distributed in approximately 18 buildings and that the Bureau is located at a distance from the center of the city, has made the work of dispatch more than usually difficult, especially under war-time conditions.

COPYING SECTION.

[Editing rough drafts of letters, reports, and manuscripts; stenography; typewriting; and mimeography.]

For convenience, and at some sacrifice of efficiency, the staff in this section is detailed to the several divisions of the Bureau. The copying of manuscripts of technical reports of researches and tests, and the work of technical correspondence, has grown very rapidly during the year. The rapid expansion of the entire Bureau and the urgency of the utmost dispatch of obtaining and publishing results has necessitated a very large addition to the staff of clerks engaged in the general work of stenography and typewriting. The sacrifice in efficiency is believed to be justified at present, since centralization would require commodious and suitable quarters. Attention is called to the urgent need for an office building of the modern type, designed and constructed throughout for the specialized work of the various sections of the office.

INFORMATION SECTION.

[Requesting, receiving, distributing, and filing of scientific and technical information of a military bearing; maintenance of a progress-of-work chart and follow-up system covering all tests, subjects of inquiry, investigations, and researches in progress for the military services.]

Progress-of-Work Records.

Some time after the entry of the United States into the war it became apparent that in order efficiently to care for the large amount

of military work regularly coming into the Bureau, it would be necessary to inaugurate some form of central progress-of-work record. Accordingly, a very efficient yet simple method was developed by which all the military tests, investigations, and inquiries for information are recorded at the time of their receipt. Thereafter, by a very simple notation, entries are made indicating the progress of the work up to the stage of the completion and mailing of the final report.

The system used, which is a novel one specially developed for the work, was described in the Journal of the Franklin Institute. The operation of the system is so carried out as to interpose no delay in the progress of an incoming inquiry or request. The aggregate of the entries currently carried on the chart is now very large in number and the record obtained, which is continually up to date, affords at all times a concise, clear-cut representation of the Bureau's activities carried on for the military services in all lines of testing, investigation, research, and compilation of technical information in answer to inquiries. Moreover, the chart discloses all cases in which abnormal delays are occurring in the carrying out of work and by the collateral employment of a follow-up or reminder system, enables the necessary corrective measures to be taken to eliminate serious and preventable causes of delay. The use of this system has already been efficacious in detecting and indicating means for correction of conditions likely to interfere with the promptest possible handling of military work.

Distribution of Military Information.

On account of the rapid changes occurring in modern warfare, with its tremendous employment of scientific and technologic resources, methods of combat and communication in use to-day are likely to be fundamentally improved or completely replaced in a very short time by a single new invention or scientific discovery. Therefore, the rapid circulation of accurate and dependable technical information to all workers in scientific and technologic fields having military application is of paramount importance. On this account and to care for the considerable mass of technical information covering every conceivable branch of physical and chemical science which the Bureau receives from the various offices of the War and Navy Departments and from research agencies of civilian character engaged in military problems here and abroad, an Information Section has been inaugurated, in which all manner of confidential information of the types just described is received. Notices of receipt and abstracts of such information are forwarded to those technical sections of the Bureau concerned with the particular subject of each document and other necessary matters relating to the distribution and dispatch of such reports are cared for.

Respectfully,

S. W. Stratton, *Director.*

To Hon. William C. Redfield,
Secretary of Commerce.

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