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ANNUAL REPORT

OF THE

DIRECTOR BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1919

(Miscellaneous Publications—No. 40)

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

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CONTENTS.

NATIONAL BUREAU OF STANDARDS

Washington, D. C.

1919

FUNCTIONS

Development, construction, custody, and maintenance of reference and working

STANDARDS - - - - - - - - - - - -

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, 1919.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1919.

I. FUNCTIONS, ORGANIZATION, 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 its 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. DEFINITION OF STANDARDS.

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 length 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

NATIONAL BUREAU OF STANDARDS

Washington, D. C.

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FUNCTIONS

Development, construction, custody, and maintenance of reference and working STANDARDS and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

STANDARDS

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.

PURPOSE

- 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.

PURPOSE

- 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.

PURPOSE

- 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.

PURPOSE

- 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.

PURPOSE

- 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.

REPORT

OF THE

DIRECTOR, BUREAU OF STANDARDS.

Department of Commerce,
Bureau of Standards,
Washington, July 1, 1919.

Sir: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1919.

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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 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 commerical transaction.

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 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.

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.

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, standard 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. In this field, as well as in the field dealing with the properties of materials, the Bureau has had the most hearty cooperation of the various Government experts, manufacturers, engineers, and the technical societies.

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 only touch upon the more important aspects of the work, where national uniformity is desired—fields which can not be covered efficiently in private laboratories.

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

Comparison of Standards of Scientific and Educational Institutions or of the Public with Those of the Bureau.

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 of measuring instruments of States, cities, scientific laboratories, educational institutions, 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. 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.

Work of the Bureau in an Advisory Capacity.

Many questions of disagreement between the public and utility companies as to matters involving the use of standards are referred to the Bureau for advice or adjustment, often avoiding unfair and 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.

The Bureau is constantly called upon to compare the weights and measures in use by State and municipal officials, as well as by the public in general, with those belonging to the Bureau. This work is of the greatest importance in bringing to the attention of the public the value of exact standards and the benefits derived through their use in ordinary life.

Likewise, a great many inquiries are received concerning the use of the various materials of construction, and the Bureau has frequently assisted in the preparation of specifications on which to base the purchase of such materials.

In the formulation of safety codes designed to govern electrical and other construction, the Bureau has taken an active part and has been represented on many committees dealing with such work.

3. RELATION OF THE BUREAU'S WORK TO THE INDUSTRIES.

Assistance in Establishing Exact Standards of Measurement Needed in Industries.

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.

Performance of Tests and Investigations and Collection of Fundamental Data.

While the greater part of the Bureau's efforts were given up during the war to work in connection with the military departments of the Government, it was never before called upon to such an extent for advice and scientific data by the industries. Most of these questions arose out of the manufacture of equipment and material of a military nature, as a large number of firms entered into this work during the war without any great amount of previous experience. A great many of these requests came directly from the manufacturers, others through the War Industries' Board, and still others from various commissions having to do with the production and commercial aspects of the war.

Every section of the Bureau cooperated to a greater or lesser extent with the manufacturers of the country, and, as a result, closer relations have been established between the industrial plants and the Bureau. It is evident that this relationship will continue and become of great economic value; but, if the Bureau is to retain its high position in the various industrial fields and meet the rapidly increasing demands for its services, the greatest amount of support possible must be given to it by the industries.

Training of Experts in Various Industrial Fields.

Through the increased activities of nearly all the industries of the country and the demand for trained investigators, the Bureau's scientific staff has been largely depleted, and it will be a matter of some time before it can be brought back to the plane of high efficiency which it has previously maintained. It is assumed that the compensation paid scientific and technical men in the Government service will be adjusted to a scale more commensurate with that paid by scientific institutions and industrial laboratories, but even then the industries should cooperate in every way possible to maintain the Bureau's staff intact and of the best material. Many instances could be given where the industries have taken experts with little warning and with no apparent consideration as to the consequences. The training of men for research is one of the most important ways in which the Bureau can aid the industries; but to do this it is necessary to maintain its own staff in the highest degree of efficiency.

4. RELATION OF THE BUREAU'S WORK TO THE GOVERNMENT.

Comparison of Standards of Other Government Departments with Those of the Bureau.

The use of exact standards enters into every branch of the Government service, as it does into every industry and into the everyday life of all persons. It was in the Government service, however, that the need for exact standards was first appreciated. The work done for the Government is in nowise different from that carried on for individuals and involves the same problems.

Many bureaus of the Government service are charged with the administration of laws and the establishment of regulations, the intelligent application of which depends very largely on the use of exact standards. This is true to a 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, Steamboat-Inspection and Coast Guard Services, and the Bureau of Navigation of the Department of Commerce, as well as all bureaus of the War and Navy Departments engaged in construction or development work.

Performance of Tests and Investigations and the Collection of Scientific Data of a Fundamental Nature.

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 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.

Advisory and Consulting Capacity.

One of the most important services which the Bureau has been able to render to other departments of the Government, both civil and military, has been of an advisory and consulting nature in matters pertaining to the scientific work in which these departments were interested. Too great emphasis can not be placed on the importance of this phase of the Bureau's work. Its maintenance would be warranted for this reason alone, even though its usefulness in this field is but a small portion of the total service which it has rendered other branches of the Government.

The Bureau's laboratories have been open and its experts available at all times to every department of the Government, and in many cases substantial help has been rendered to the military and civil departments through the familiarity of the Bureau with certain kinds of work, and its ability to quickly decide whether the particular methods, materials, or devices were suitable for the service in question.

The Bureau as a Testing Laboratory and Its Work in the Preparation of Specifications on Which to Base the Purchase of Materials.

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 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 Corps of the Army, the Bureau of Supplies and Accounts 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.

5. RELATION OF THE BUREAU TO THE MILITARY SERVICES DURING THE WAR.

Aid in the Development of Devices for Military Purposes.

The war brought about the most rapid and intense application of science the world has experienced. Scientific research received a stimulus that extended far beyond military fields and produced results of great permanent value to the industrial, as well as the military, world. The Bureau cooperated with the Army and Navy in the solution of their scientific problems relating to the development of all sorts of devices for military purposes, and was frequently called upon for advice by those manufacturers who during the war entered the field of producing military equipment for the first time. The experience gained through the investigation of these problems had many useful applications in the fields of industry without in any way revealing the military nature or value of the particular results sought.

The Bureau was exceedingly fortunate in securing substantial appropriations from Congress for carrying on work of this character in cooperation with the Army and Navy. The various bureaus of both these departments not only devoted funds to scientific research wherever necessary, but their cooperation with the Bureau of Standards was all that could be desired, and they should be given the greatest credit for utilizing the resources of the Bureau to their fullest extent.

Many cases might be cited where the Bureau undertook the development of military devices by its own staff or in cooperation with the experts of the Army, Navy, or manufacturers. A few characteristic and important examples which may be cited are: The development of sound-ranging devices in cooperation with the Engineer Corps of the Army; the production of an electrical device for synchronizing airplane machine guns and propellers; the application of the radio compass to both air and water navigation; the development of instruments for the navigation of air craft; the production of a hydrogen detector for submarines; and the development of all sorts of optical instruments for purposes of observation, range finding, and navigation. Work in cooperation with the Inventions Section of the General Staff has resulted in great improvements in the design of rifles, machine guns, and many other devices for like use. An elaborate investigation of methods of signaling by the use of invisible rays and the development of devices for the detection of secret writing may likewise be cited. In the field of aeronautic power plants, a special carbureter for air-craft engines and a high-speed gas-engine indicator were developed, together with other devices for aviation use. A great deal of work was done in connection with aerial photography for the Signal Corps, and, as a result of this investigation, a special hypersensitized plate was produced.

Development of New Materials.

As mentioned in the preceding paragraph, the stimulus of the war was felt in every branch of the industries. Not only were new devices produced for military purposes, but certain entirely new materials were developed. The shortage of raw materials in certain lines, caused by the cutting off of the supply from Europe, led scientific men to turn their attention to the production of satisfactory substitutes, and to the use of many familiar materials for novel purposes. Thus the manufacture of optical glass in this country (a material formerly produced only in Europe) was proven to be a commercial proposition through the elaborate investigation which had been carried on by the Bureau even before the war. In like manner the shortage of linen led the Bureau to develop a satisfactory cotton fabric for use in covering airplane wings. A filter paper for gas masks was produced, and many specifications were prepared for all sorts of materials, such as prepared roofings, wall board, plaster board, cement, concrete, etc. New paints, designed for the protection of the interior of shells, the holds of vessels, as well as waterproof glues and varnishes, were developed through the Bureau's efforts. In all this work the Bureau cooperated with the military departments and the manufacturers, often acting merely in an advisory capacity, but more frequently carrying out complete investigations in each of the particular lines. Here, again, the information gained in reference to materials for military work has even a greater value in connection with the industries. There are few cases where the military and industrial interests were not equally important.

Activities in the Field of Aeronautics.

The Bureau has engaged in researches and tests in connection with the determination of important fundamental data needed in aeronautics; the investigation and test of instruments, devices, and materials used in air craft for the air services of the Army and Navy, the National Advisory Committee for Aeronautics, the Bureau of Aircraft Production, and for manufacturers—a service which has resulted in great permanent value to both military and civil aeronautics and to those employing internal combustion engines.

This work has included tests in the altitude laboratory on various aeronautic engines to determine the variation of horsepower with altitude, compression ratio, and air temperature; the value of supercharging devices designed to enable airplanes to attain higher altitudes; the comparative values of various aviation fuels; the preparation of specifications for special aviation gasoline; and the relative merits of different carburetors, radiators, and other apparatus. A complete investigation of airplane ignition systems, including tests of magnetos and spark plugs, the development of a special improved spark-plug porcelain; investigation of the strength of materials used in the construction of airplanes; tests of all kinds of aeronautic instruments and development of certain special devices; aerodynamic tests of aerofoils and model airplanes; tests and the preparation of specifications for lubricating oils; tests of fabrics and airplane wings, and the development of a satisfactory cotton fabric; investigation of devices for synchronizing machine-gun fire with airplane propellers; study of self-luminous materials for use on the dials of aeronautic instruments; routine tests and development of special varnishes for airplanes.

Activities in the Field of Metallurgy.

In this field the Bureau has cooperated with the Army, Navy, the National Advisory Committee for Aeronautics, and other military bureaus. The work has covered a complete investigation of aluminum alloys for use in the building of air-craft engines, etc., Government bronzes, development of special steels, investigation and development of satisfactory aluminum solders, and the preparation of specifications for bearing metals. A large amount of routine testing of gun steel and similar work was carried on.

Activities in the Field of Electricity.

In the field of electricity the Bureau has continued to do a great deal of routine testing, including the acceptance tests of lamps and other electrical appliances for the bureaus of the War and Navy Departments. It has also carried on a number of complete investigations, among which may be mentioned the development of a satisfactory synchronizing device to be used in connection with machine guns designed to fire between the blades of airplane propellers, tests of electric trucks and tractors, development of radio apparatus, and a study of the fire-control system in battleships. A special manual has been prepared for radio operators, and the possibilities for the improvement of means of insulating cable, such as those submerged in salt water, have been investigated. Many such cases could be cited.

Activities in the Field of Chemistry.

In cooperation with the Gas Defense Service, the Bureau tested a number of materials for the construction of gas masks and studied the composition and effects of poison gases. A very large number of routine analyses were carried out for the various branches of the Army and Navy, these usually taking the form of acceptance tests of materials.

Owing to the shortage of suitable dyes for use in manufacture of Army uniforms, American manufacturers were early called upon to supply dyes from this country. The Bureau carried out an investigation of textile dyes and aided in the preparation of suitable specifications to be used in their purchase. It also assisted in the development of satisfactory methods for the testing of materials for Army uniforms as to dye fastness and other chemical properties.

Other work included the development of special paints, enamels, varnishes, and protective coatings and the preparation of specifications for the same. During the war a great number of buildings of a temporary character were erected, and, in connection with these, a very large quantity of prepared roofing was purchased. The Bureau undertook an investigation of this class of materials, and, as a result of the work, was able to furnish to the organizations interested a satisfactory specification for such roofing.

Development of Optical Glass and Optical Instruments.

For a number of years the Bureau has carried on experimental work with a view to assisting in the manufacture of optical glass in this country. This has involved a rather complete investigation of manufacturing processes and the making of a considerable amount of glass in the Bureau's own shops, which was utilized for military purposes. The information thus gained in regard to the pots used and materials involved, the technique of the furnace, the molding, annealing, testing, and inspection of glass was given freely to those manufacturers who were engaged in the manufacture of optical glass to supply the large and sudden demand for it in the construction of military optical instruments. The Bureau's plant will be maintained on an experimental basis and should render valuable assistance in the maintenance of the optical-glass industry in this country. (The importance of this work was emphasized during the war, as the foreign supply of this kind of glass was practically cut off.)

The importance of optical instruments is, of course, recognized at all times, but during the war the demand for suitable binoculars and field glasses was unusually acute. The test of such instruments has been carried on for the Army and Navy, and, in general, American makers have turned out a very satisfactory product. The bureau has cooperated in the specification, testing, and standardizing of the optical instruments used in military work.

An elaborate investigation was conducted on the use of ultra-violet light for signaling purposes. By the use of a source of such light and a suitable glass through which to view it a means of signaling, invisible to the naked eye, was developed for the Signal Corps of the Army and the Bureau of Steam Engineering of the Navy. Unusually rapid photographic plates for airplane cameras were investigated and a satisfactory panchromatic plate developed.

Organizations with Which the Bureau Cooperated During the War.

Civil organizations: Aircraft Board, Emergency Fleet Corporation, National Research Council, War Industries Board, National Advisory Committee for Aeronautics, United States Railroad Administration, Bureau of War Risk Insurance, American Red Cross, and others.

United States Army: Air Service, Coast Artillery Corps, Construction Division, Engineer Corps, Field Medical Supply Depot, Inventions Section General Staff, Motor Transport Corps, Ordnance Department; Purchase, Storage, and Traffic Division; Quartermaster Corps, Signal Corps, and others.

United States Navy: Bureau of Construction and Repair, Bureau of Ordnance, Bureau of Steam Engineering, Bureau of Yards and Docks, Hydrographic Office, Office of Naval Intelligence, various navy yards and naval bases.

6. 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 is so important that a division known as the metallurgical division was 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.

7. 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.]

The urgency of the testing work for the military departments during the war led to the deterioration of the apparatus, which was corrected as soon as the opportunity offered itself. The condition of all of the comparators and standards was carefully studied, and steps were taken to place them in first-class condition.

The desirability of controlling the temperature of the room in the basement in which the meter comparator is installed has long been recognized, but for the reasons mentioned little progress in carrying out the plans had been made until the signing of the armistice released some of the energies previously tied up. During the year the interior of the room was insulated from the outer walls. Also a regulating thermostat and heating and cooling coils were either constructed in the shop or ordered from the manufacturers. It is expected that arrangement will make it possible to control the temperature in the room to within 0.5° centigrade. More perfect control of the standards at any time under investigation will be secured by placing them in insulated containers to protect them from fluctuations of the room temperature, the main consideration usually being that the two standards under investigation shall be at the same known temperature.

Investigations have also been conducted to determine the best method of illuminating the standards. The apparent shifting of the lines on the standards when the prisms mounted under the microscopes are moved was eliminated by placing a thin sheet of xylonite, one surface of which has been slightly roughened, under the prisms.

Paint Films.

Certain considerations have indicated that one element of proper specifications for paint should probably be the thickness of a coat of it on a metal plate under certain specified conditions. In a study of this subject by the chemistry division it was realized that in order for measurements of this film thickness to be practical a simple device must be employed. To that end experiments were made by this section which resulted in the conclusion that a dial gauge could be employed, a rather stiff and plane metal plate being used for the film of paint and measurements taken at various designated points both before and after the paint had been applied. Three points of support for the plate were suggested as preferable from a number of considerations. With a special device of this character the chemistry division has been continuing the investigation.

In a special test, films of the paint used on ordnance shells gave a very consistent series of results. One of the specific points in view was to determine whether the film was sufficient for protection and yet thin enough to insure that there would be no interference or rubbing when fired.

Oscillograph Films.

An investigation of the accuracy with which oscillograph films used in ballistic work could be measured by different methods indicated the best methods of measurement and the accuracy to be expected. One of the singular facts, probably due in part to physiological and psychological causes, which was noted in this investigation, was that more accurate results seem to be obtained by moving the cross hairs of a micrometer microscope until a line ruled on the object at the focus of the objective is exactly between these cross hairs, than to move the object slowly until the line appears to be between the cross hairs. This would seem to have a rather wide range of application to many measuring devices and possibly to other instruments.

Meter and Yard Bars.

The Canadian Government at Ottawa submitted one of their principal standards of length for a determination of the total length. As it had at some time previously been tested at the National Physical Laboratory in England, and, as a rather complete intercomparison of several meters belonging to this Bureau was made in connection with the Bureau's test, it is believed that the final results may give additional facts concerning the changes which may occur in a length standard during the course of time.

Sieves.

Few articles tested by the Bureau have as wide a range of use as sieves. Among the users may be mentioned the cement, fertilizer, mining, metallurgical, abrasive, chemical, drug, and sugar industries. The attention of this section has been especially devoted to the finer-meshed sieves. In the case of 200-mesh sieves a very noticeable improvement in American-made cloth has been noted during this last year.

Because of the large amount of explosives used by the Government, and because of the need of rather strict specifications for the ingredients, this Bureau rendered considerable assistance in giving advice as to the proper specifications for the sieves and in settling various disputes which arose from the fact that in many cases there exist several distinct sieves of different make, all designated by the same mesh. In compliance with many urgent demands, the standard scale for testing sieves adopted in 1916 has been revised. In the revised scale not only the size of the openings, but also the diameters of the wires, form a regular and continuous sequence from the coarser to the finer sieves. The ratio of openings is $\sqrt[4]{2}$ throughout, and each sieve is designated by a number approximately equal to the mesh per linear inch. This revised scale has been sent to those believed to be interested, and from the many favorable replies so far received, its early adoption seems assured. Although primarily intended as a standard for testing sieves its application is by no means thus limited, the rather strict tolerances being omitted or modified when the sieve is to be used for general routine or commercial sieving.

Routine Testing.

The following is a list of articles tested by the length section during the year, with the fees charged:

	Fee.
12 meter and yard bars	$64.00
575 hæmacytometers	930.00
152 sieves	175.20
8 samples sieve cloth	11.60
43 polariscope tubes	17.60
6 viscosimeters	18.00
27 level rods	76.50
31 invar tapes	224.50
128 metallic warp tapes	95.25
114 steel tapes	97.55
2 spring balances for tapes	.50
33 articles for contact measurements	54.25
40 articles for line measurements	197.00
8 articles for angular measurements	19.50
3 Brinnel microscopes and 1 Ames dial	8.00
42 miscellaneous articles for test	75.00
10 miscellaneous articles for ruling	100.00
Total (1,234 articles)	2,164.45

MASS.

(The comparison of precision weights with the standards of the Government, the preparation of specifications and tolerances for weights and balances, improvement in design of balances, solution of fundamental problems arising in connection with weighing, precision weights, and balances.)

A Publication on Weights.

The revised edition of Circular No. 3, "Design and Testing of Standards of Mass," was published in December. Besides the new regulations in regard to testing and fees, it contains detailed descriptions of the requirements as to structure and accuracy for the classes of weights now recognized by the Bureau and the purposes for which they are intended, also a considerable amount of information concerning air buoyancy and its effect on weighing, and a fairly detailed description of the methods used in calibrating weights, with forms for computing the corrections. The circular should be of use to anyone wishing to calibrate a set of weights from a few certified standards, as well as to those using Bureau of Standards' certified weights for very high accuracy weighing, and

142289—19——3

to people wishing to buy or make high-grade weights for various purposes.

Advice.

A considerable amount of advice and information about balances and weights has been furnished orally or in writing to members of the Bureau and to men from other Government departments and from private organizations.

Cooperation with the War Department and Others.

The section has cooperated with the War and Navy departments by making considerable numbers of miscellaneous weighings for them, including weighings of machine-gun parts, cartridges, etc., and by some loans. It has also aided other sections of the Bureau, both by making weighings for them, including a series of weighings on specimens for the thermal-expansion laboratory, and by lending balances and weights for occasional use.

Work with the Bureau of Markets on the Problem of Grading Wheat.

The section has been cooperating with the inspection service of the United States Bureau of Markets in improving a device for determining the weight per bushel of wheat from samples, as a basis of grading it. In connection with this work four grain testers have been tested for the United States Bureau of Markets and one for the State of Kansas, and some improvements suggested and adopted. A large number will probably be tested during the coming year.

Effect of Brittle Lacquer in Rendering Weights Unreliable.

That the loss of weight caused by brittle lacquer breaking off in ordinary careful handling may be large enough to be serious for some kinds of chemical weighing was shown by a retest of three sets of weights which had been in use for a short time only in the chemistry division of the Bureau. In several cases the loss was over a milligram for a single weight, although there was little appreciable wear except on the neck of the knob where the tweezers grip the weights.

Unsatisfactory Weights.

Much delay and extra work has been caused by rejections made necessary by the inaccuracy of weights submitted for test. Most of the class S sets have contained weights which were out of tolerance when first submitted. This widespread inaccuracy and frequent cases of unsatisfactory finish—slivers, inadequate plating, brittle lacquer, etc.—are probably due in a large part to unsettled conditions caused by the war. The need of testing new weights is continuously being shown by the discovery of poorly constructed or seriously inaccurate weights.

Effect of Variations in Humidity on a Sensitive Balance.

An investigation of the irregular and unreliable behavior during the spring and summer of a new assay balance (supplied by the maker in place of the one mentioned last year, which had proved unsatisfactory for the rapid testing of small analytical weights, for which it was bought) disclosed the interesting fact that this balance is highly sensitive to changes in atmospheric humidity. An exhaustive study to determine the exact seat of the trouble has been planned, but only a small part of it has been carried out as yet, owing to the pressure of other work. The failure of this balance has more than doubled the time required for testing the milligram weights of each "analytical set," since it has been necessary to return to the longer methods of calibrating to secure the required accuracy.

Changes in the Precision Weighing Laboratory.

During the earlier part of the year the work was hampered by the confusion incident to interchanging the weighing rooms. The time spent in planning the details of the new weighing room resulted in an arrangement at once more compact and more convenient than the former one. Also temperature conditions are much more constant in the new room than in the old.

Routine Testing of Weights.

The total number of weights tested during the year was 2,594, a decrease of about 5 per cent as compared with the year previous. Of these about 51 per cent were for private parties—mostly commercial companies—25 per cent were for our own Bureau, 5 per cent for the War and Navy Departments, 9 per cent for other branches of the Federal Government, especially the Treasury and the Department of Agriculture, and about 5 per cent each were for the States and for the educational institutions, respectively.

Testing of Balances.

The number of balances tested was unusually large—36 as against 22 last year. These were mostly for various divisions of this Bureau.

Visitors.

The growing interest of the general public in the work of the Bureau is shown by the increasing number of visitors who have come to see the precision weighing laboratory and its work. A record kept during several typical weeks in the spring shows that during that season the average number of visitors per month was about 90. The amount of time required to show them the laboratory totaled more than three working days each month. This does not include any of the large groups from schools which occasionally came through, nor those who were attending the Physical Society meetings or the Weights and Measures conference at the Bureau. During the four days of the latter conference there were 53 visitors, taking seven hours' time.

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.)

During the year the following apparatus was tested as to compliance with the specifications promulgated by the Bureau:

Apparatus.	Number submitted.	Tested.	Passed.	Fee.
Burettes	418	330	252	$361.50
Cylindrical graduates	3	3	....	2.15
Dilution pipettes	1,353	1,325	1,076	1,153.20
Flasks	1,648	1,383	1,021	521.65
Pipettes, transfer	713	646	459	218.05
Pipettes, measuring	131	109	62	138.45
	4,266	3,796	2,470	2,395.00
Hydrometers	1,042	1,023	853	1,165.25
Salinometers	180	180	....	90.00
Special apparatus	151	107	....	114.55
Weighings	56	56	....	28.00
Density determinations	....	262	....	262.00
				4,054.80

Fifty-eight per cent of the volumetric apparatus submitted passed the test of the Bureau, while of that actually tested 65 per cent passed.

Of the hydrometers submitted for test, 82 per cent passed, while of those actually tested 83 per cent passed the test of the Bureau.

GAUGE WORK.

(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.)

The gauge section was organized as a part of the division of weights and measures at the beginning of the war to provide facilities on a larger scale to inspect and certify limit gauges and precision-length standards and to assist in the solution of problems arising in connection with gauge work.

The staff of the section numbered about 140 on July 1, 1918, and had further increased to 225 in November of the same year. By July 1, 1919, the number had been gradually reduced to 55 members.

Scope of Work.

Besides the routine testing of gauges at the Bureau in Washington, the section during the past year conducted branch laboratories; developed and manufactured Hoke precision gauges; improved, designed, and constructed gauge-testing apparatus; salvaged and manufactured limit gauges; stored, shipped, and conducted a clearing house for master gauges; conducted instruction forces for Government gauge inspectors; studied gauge and tolerance problems for the National Screw Thread Commission; and prepared and distributed communications and reports regarding such parts of the above work as are of general interest.

Appropriation and Allotments.

The section carried on its work under an appropriation of $150,000 for gauge standardization. This was supplemented by allotments totaling $233,000 made "to take care of expenses in connection with the salvage and manufacture of master gauges for the inspection Division, Ordnance Department." Another allotment of $50,000 was made by the Engineering Division of the Ordnance Department for experimental work and manufacture of precision gauges.

Gauge Testing.

The number and lots of gauges submitted for test, month by month, are shown in the following table, which includes the work at Washington and the three branches:

Date.	Number of lots.	Number of gauges.	Date.	Number of lots.	Number of gauges.
July, 1918	413	5,733	February, 1919	102	1,596
August, 1918	523	5,513	March, 1919	89	978
September, 1918	488	5,050	April, 1919	86	644
October, 1918	660	5,813	May, 1919	79	481
November, 1918	521	5,984	June, 1919	51	2,253
December, 1918	478	4,218			
January, 1919	218	2,367	Total	3,708	40,630

Of the above gauges about 45 per cent were classified as screw-thread, 45 per cent as plain, and 10 per cent as profile, fixture, and miscellaneous types.

During the war the inspection was handled with such dispatch that the average time between the date of arrival and completion of tests and reshipment was from three to four days.

Branch Laboratories.

The three branch gauge-testing laboratories were located in New York City; Cleveland, Ohio; and Bridgeport, Conn. Each was equipped with facilities duplicating on a small scale the Washington laboratory. These branches served a large number of manufacturers in the industrial centers in which they were located and aided materially gauge production by making it possible for manufacturers to send sample gauges and work by messenger for immediate inspection. All of the branch gauge laboratories have been discontinued on account of the lack of funds.

Development and Manufacture of Precision-End Standards.

In July, 1918, experimental work was begun to demonstrate the feasibility of mechanical production of precision-end gauges under the direction of the inventor, W. E. Hoke, and in cooperation with the Bureau's experts in optical methods of measurement, which are essential. (For details of this work, see report of the optical section.) An early set of samples of equal length with 0.000002 inch, flat within 0.000004 inch, and within 0.000008 inch of the desired size has proved the practicability of the method. Upon receipt of this report the Ordnance Department made an allotment to cover manufacturing cost and commissioned the inventor. Bureau machinery and other machinery and special apparatus purchased under the allotment was installed and manufacture begun. By the close of the year more than 3,500 gauges had been manufactured, accurate within 0.000005 inch, and assembled in sets the total value of which, compared to the price of the formerly imported gauges, exceeded the amount of the allotment. The cost of experimental work and all machinery purchased was in this manner virtually saved by the Government in the first year's production.

Gauge Storage and Distribution.

Following inspection and acceptance by this Bureau of master gauges purchased by and for the use of the Ordnance Department, gauges were classified and stored to await shipping instructions to points where munitions were approaching completion and master gauges would be required in connection with their acceptance. Between two and three thousand gauges were stored and shipped monthly in this manner. After the general cancellation of munitions contracts all the remaining gauges at the Bureau, except three or four thousand, representing one of each type and size. were shipped to arsenals designated by the Ordnance Department. These remaining gauges are in possession of the Bureau, subject to call for reference purposes.

Gauge Salvage and Manufacture.

During the year 487 new master and inspection gauges were manufactured, and 962 additional obsolete gauges were salvaged for the Ordnance Department to conform to revisions in the designs of munitions components for which the gauges were originally procured. This was done as exigency work in the gauge shop only when serious delay would result from the regular method of procuring gauges from outside manufacturers through obtaining bids and placing contracts, or when a small amount of work would salvage obsolete gauges and save the much larger expense of contracting for entirely new gauges.

Five additional lead testers were manufactured for the Ordnance Department during the past year, so that one machine has now been supplied for each of the principal arsenals.

Instruction Courses.

Three two-week courses of instruction covering the measurement and use of our special gauge-testing apparatus and study of methods particularly adapted to field work were given at the Bureau. The courses were attended by a total of 50 supervisors and gauge inspectors, among whom were represented 13 district ordnance offices, 2 navy yards, 2 arsenals, the Motor Transport Service, and 4 large manufacturers having war contracts.

Design and Construction of Apparatus.

The following new designs of gauge-testing apparatus have been made to embody the results of experimental work: Simplified projection lantern of short range with horizontal projection, ground-glass screen, and equipped with incandescent arc illumination; an improved and simplified balanced micrometer to be used for pitch-diameter measurements of thread gauges by the three-wire method; a mechanical indicator to replace the optical lever system on the Bureau's lead-testing machines; apparatus for the measurement of periodic lead errors in plug-thread gauges; a device for standardization of wire measurements.

Apparatus and instruments are under construction at the present time for all of the above designs. In addition to this work, the shop has built during the past year practically all of the special apparatus required for the Washington laboratory and branches.

Research.

Research work has been carried out largely in connection with problems of the National Screw Thread Commission. Experiments have been made to determine suitable tolerances, allowances, and interference values for various classes of fit. Study has been made of methods of manufacturing taps and screw-thread gauges, together with the effect of errors in taps on the size and character of tapped holes. Proposed tolerance systems have been worked out, tabulated, and charted. Questionnaires have been prepared and issued, through which information has been secured from manufacturers and users of screw-thread products relating to current practices. Replies have been studied, classified, and tabulated.

Reports on Communications.

The following mimeographed communications which have been prepared or revised during the year are available for distribution:

- B461. Symbols for screw-thread notation and formulas.
- B466. Procedure of tests and explanation of reports of munition limit gauges by Bureau of Standards.
- B467. Gauge tolerances used by Ordnance Department, United States Army.
- B506. Important screw-thread systems.
- B507. Shop inspection of taper-thread gauges.
- B510. Construction and operation of projecting apparatus for measuring screw-thread gauges and profiles.
- B512. Interchangeability of United States standard and British standard Whitworth threads by diameter modification.
- B513. Services available at the Bureau of Standards gauge laboratories.
- B514. Drawings and explanation of drawings used in manufacture of pitch-testing device.
- B516. Important European screw-thread systems.
- B517. Thread form and clearance of thread gauges.
- B519. The measurement of radii on profiles.
- B520. Testing of flatness of gauging surfaces.

A number of articles regarding the work of the gauge section have appeared in various mechanical trade journals and scientific magazines.

Program.

A large amount of valuable data have been collected relating to all phases of war-time gauge work of the Bureau. From experience it has been possible to advise manufacturers on a great many subjects relating to the proper design, inspection, and use of limit gauges. This work is being continued and will be supplemented by literature prepared and distributed in such a manner as to reach and benefit the largest number of manufacturers and interested parties possible. Standardization, research, routine testing of commercial gauges and standards, and development of measuring apparatus will form important parts of the future work of the gauge section.

TIME-MEASURING DEVICES.

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

Practically the whole efforts of the time section have been devoted to the testing of timepieces for the United States Shipping Board. This work, unlike other work, began during the war, and was not discontinued at the signing of the armistice, as the original shipbuilding plans of the Government were not thereby greatly modified.

This section has completed the following tests during the year:

Kind.	Number tested.	Length of test in days.	Fees.	Kind.	Number tested.	Length of test in days.	Fees.
Class A watches	82	54	$311	Airplane clocks	33	12	$132
Ship watches	1,395	31	6,975	Chronometers	9	31	95
Comparing watches	1,360	16	1,360	Investigation	2	31	10
Stop watches	1,996	a 12	594	Master clock system	1	100	5
Wrist watches	200	12	50				
Deck clocks	4,778	21	4,778	Total	9,856	....	14,310

a Minutes.

Of the 82 watches submitted to the class A test, certificates were granted to 19, of which 17 were of American manufacture and 2 European; certificates were refused to 63 watches, of which 25 were of American manufacture and 38 European.

GAS MEASUREMENT.

(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.)

Testing of Town-Border Natural-Gas Meters for United States Fuel Administration.

In connection with its program of conservation of the natural-gas resources of the United States, the United States Fuel Administration requested the Bureau to test the natural-gas meters established at the town borders of a large number of cities and towns of Kansas and Missouri. Accordingly, the Bureau sent into these States members of its staff, who during the months of November and December, 1918, and January, 1919, tested a total of 103 large meters. Of these 12 were proportional meters, 2 pitot-tube meters, 33 orifice meters, and 56 positive-displacement meters.

On the basis of the Bureau's findings and the price of artificial gas, it has been estimated that during 1918 several million dollars' worth of gas was lost by leakage in the distributing plants receiving gas through the the meters tested.

Meters Tested in the Laboratory.

A considerable number of meters of miscellaneous types were tested in the laboratory. These meters were all for use in testing and research work by the War Department and various scientific institutions.

Investigation of Claims of Tide Motor for Post Office Department.

Upon request of the Post Office Department, the Bureau examined the claims made for a tide motor which was being advertised through the mails. The exhaustive examination made of these claims showed them to be false, and, as a result, the use of the mails in advertising the device was prohibited by the Post Office Department.

Consultation.

The Bureau has been consulted frequently by Government departments and others regarding the solution of gas-measuring problems and has usually been able to give material aid.

Publications.

Household Weights and Measures, Miscellaneous Publication No. 39. This consists of a card designed to be hung in the kitchen, which contains a large amount of weights and measures information frequently of use in the household.

Orifice-Meter Investigation.

Preliminary work has been commenced on the determination of the coefficients of orifice meters for gas measurement. It is planned to make a thorough investigation of this type of meter in order to correlate and verify the work previously done by various investigators. These coefficients involve accuracy of the measurement of large quantities of natural gas, air, and steam.

Photographic Method of Detecting Camouflage and Changes in a Complicated Group of Objects.

The Bureau devised and developed, in cooperation with the United States Signal Corps and United States Air Service, a photographic method of detecting camouflage. The method consists of making two photographic negatives of the group of objects, one before the change and the other afterwards. A positive is made from one of the negatives, and this is superposed upon the other negative. If no change had occurred between exposures, the combination would form a field of practically uniform photographic density; but changes are plainly indicated by discontinuities of density. It is believed that the method has considerable commercial value for engineering work, detective work, etc.

THERMAL EXPANSION.

(Determination of thermal expansion of various materials.)

The expansion of a number of special alloys and materials over considerable range of temperature were studied during the year. The curves of a number of these materials were determined for the first time, and consequently they constitute valuable contributions to the available scientific and technical data. Altogether 121 specimens were studied, the materials being as noted below:

Material.	Number tested.	Schedule fee.	Material.	Number tested.	Schedule fee.
Copper alloys	49	$735	Limestone	1	$25
Steel	32	1,876	German silver	1	33
Porcelain	23	784	Hard rubber	1	38
Bakelite	4	137	Stellite	1	55
Marble	4	82			
Celluloid	3	68	Total	121	3,933
Molybdenum	2	100			

Over one-half the above tests are in response to military requests.

Researches.

Porcelain.—Most of the porcelains were tested in connection with the Bureau's spark-plug research conducted at Pittsburgh and Washington. Expansion data are very essential in this work, since it is necessary to have the expansion of porcelain matched by that of the metallic electrodes if cracking is to be prevented.

The 49 copper alloys are a part of the original 129 submitted in July, 1916, by the American Brass Co. as a cooperative research. There still remain 10 specimens in this lot.

Dental Amalgams.—An extended series of experiments on dental amalgams were conducted at the request of the Surgeon General of the Army. There are no definite specifications for these materials. Personal opinion and crude tests have been relied upon in the past in grading them. Because of the complexity and minuteness of the dimensional changes taking place during the amalgamation of alloys interference methods have to be employed to study them.

The net result of all tests has shown that many alloys sold as "balanced" or "according to certain principles" in no sense develop the qualities which are supposed to accompany such products.

Comparative results on 12 alloys submitted to the Surgeon General of the Army for purchase were recently completed. This will be used as a basis for making decisions until permanent specifications are written.

Permanent specifications are to be prepared by this Bureau, with the cooperation of the Research Institute of the National Dental Association.

Dividing Engine.—Finding it impossible to repair or improve the present equipment of dividing engines in use or to purchase satisfactory ones, the Bureau has begun the design of new machines for future use. A study has been made of the design and accuracy of existing machines, and from this it is hoped the Bureau will be able to improve its equipment of apparatus.

New Expansion Furnace.

The new high-temperature (1,000° C.) furnace for thermal-expansion measurements has been installed and is giving excellent satisfaction. Numerous tests of steel and iron have been carried beyond the recalescence temperature and detailed information secured in this region.

By attaching the position wires in V notches cut in the side of specimens it has been found possible to eliminate the errors due to blisters which appear on specimens heated above 700° C.

Publications.

Bulletin 15 will include a paper on "Thermal Expansion of Molybdenum" issued by this section.

A second paper, "Thermal Expansion of Porcelain, Phenol Products, Marble, etc.," is now in the hands of the editorial committee.

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.)

Mine-Scale Investigation.

The investigation of mine scales has been continued, and the work has been carried into several new fields, notably in Ohio, West Virginia, and Kentucky. There is a great demand for work of this character, and it is being pushed as rapidly as possible with the facilities at hand. Very bad conditions have been encountered and rectified in the various regions, and many complaints have been investigated and amicably adjusted. As a result, a better understanding between the miners and operators has been created and greater efficiency in this industry is thus being brought about.

In Maryland serious inaccuracies of scales were found in a number of cases, and faulty and unlawful methods of weighing and incorrect tare weights were found in use. In order to rectify these conditions, a number of cases were brought to the attention of the Grand Jury by the State's Attorney, and at his request representatives of the Bureau appeared before the Grand Jury and testified as to conditions found. A number of indictments were obtained, and the cases were tried in the State courts. Several convictions were obtained, while in other cases the defendants were found "Not guilty" on account of lack of knowledge as to the inaccuracy of their weighing equipment. The cases had the result of effectively demonstrating the necessity of regular tests, quieting the suspicions and discontent of the miners and clarifying the meaning of the State mining law.

Railroad Track-Scale Investigation.

The testing or railroad-track scales has been continued throughout the year, although it has been found impossible to keep the equipments in the field at all times on account of lack of sufficient funds for this work. The Bureau has continued to cooperate with the United States Railroad Administration under the terms of Circular No. 13 of that administration, and reports of all tests of track scales belonging to the railroad companies have been furnished to the regional directors and the Federal managers of the roads concerned. Many of these officials have been making a determined effort to improve conditions on their lines, and in these cases the recommendations of the Bureau have been promptly complied with. As a result, in some sections conditions have doubtless been very materially improved. Ten master scales on the various lines have also been inspected and tested in order to maintain the standard of weight of the test cars operated by the railroad companies.

While special attention has been paid to scales belonging to the railroad companies as mentioned above, nevertheless a number of industry track scales, especially where tests were requested by railroad companies and State departments, have also been tested in connection with this work. Track scales have also been tested for the Government, States, and cities.

A summary of tests made follows:

Scales tested.	Number tested.	Correct.		Incorrect.	
		Number.	Per cent.	Number.	Per cent.
Railroad track scales	352	153	43	199	57
Industry track scales	312	156	50	156	50
Government, State, and city track scales	17	4	24	13	76

The tolerance allowed on the track-scale tests is the same as in former years, namely, a maximum allowable error of 200 pounds in weighing a car of 100,000 pounds, gross weight.

Some idea of the extent of the distribution of the above work may be gained from the fact that scales upon the lines of 78 different railroads were included, tests being made in the District of Columbia and the following 32 States: Alabama, Arkansas, Colorado, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Maine, Massachusetts, Michigan, Mississippi, Minnesota, Missouri, Montana, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Ohio, Pennsylvania, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Wisconsin, and Wyoming.

In addition to tests made above, some special investigations of locomotive scales have been undertaken at the request of the U. S. Railroad Administration at seven plants with which the latter has contracts for furnishing new locomotives. These locomotive scales are scales of special design for the purpose of determining load distribution on locomotive drivers. The work has been completed in 3 of these plants, 29 scales of this type having been tested. Many of these were found to be of faulty design and very seriously inaccurate.

Inspection and Test of Other Weighing and Measuring Apparatus.

Inspections and tests of a number of weighing and measuring devices have been conducted in order to ascertain whether their construction and accuracy were suitable for the purpose for which they were intended. This work was done at the request of various Government departments, manufacturers, State officials, and others, and included the investigation of several new types of liquid-measuring pumps. Tests were also made of a number of large-capacity scales at the Washington and Philadelphia Navy Yards. Also early in the year, representatives of the Bureau made very extensive tests of the weighing equipment at the Government powder-manufacturing plant, at Nitro, W. Va., in order to enable that plant to get into production. In compliance with an urgent request of the War Department, a special investigation was made of the weighing equipments at the Government powder-bag-loading plants located at Woodbury, N. J., and Tullytown, Pa. These plants were just beginning to operate at that time, and, since they were constructed primarily to supply powder charges to the American Expeditionary Forces in France, it was important that they be equipped with the best weighing apparatus and use the best weighing methods, so that maximum production could be obtained. A detailed report was made of the conditions found, and recommendations were included which were immediately put into effect by the War Department officials.

Standardization of Large Test Weights.

The large test weights—namely, 10,000 pound and 2,500 pound weights—which make up the 100,000-pound loads on each of the test cars Nos. 1 and 2, were brought to the Bureau of Standards for recalibration. Since these weights are carried inside of a freight car, they are not subject to change in weight due to excessive wear, loss of parts, etc., as is the case with the railroad type of scale test car and therefore do not require checking so frequently. However, there is a slight change in their weight due to wear of paint, oxidation of iron, etc., which makes recaliberation from time to time necessary.

All of the weights were repainted and adjusted. After this adjustment the probable error of each set of 100,000 pounds is 0.1 pound, or inaccuracy of 1 part in 1,000,000.

Specifications for the Manufacture and Installation of Railroad Track Scales for Ordinary Freight-Car Weighing.

The entry of the United States into the war delayed the issuance by the Bureau of Standards of final specifications for railroad track scales, which had been previously issued in preliminary form for comments. The subject of railroad track scales was, however, a matter of too great economic and industrial importance to abandon entirely. After the war work had become organized and under way, it became possible to give increasing attention to track scale matters. The Bureau has always made it a point to cooperate with all who have a legitimate interest in this subject, including the officials of States, railroads, manufacturers, and private concerns.

The regional director of the United States Railroad Administration for the Northwest region called together a meeting in Chicago to discuss the specifications which the State of Minnesota had adopted and were planning to put into effect on December 1, 1918. On account of war conditions it was desired to postpone the date at which these would be effective, since to meet the specifications would hamper the railroads under war conditions. The representatives of the State of Minnesota agreed to this, and the purpose of the meeting was accomplished. Furthermore, there was an apparent spirit of cooperation present which was promising. As a result the regional director for the northwest suggested that a committee be formed for the purpose of harmonizing the specifications for railroad track scales prepared by different agencies. This suggestion was acted upon. The Bureau of Standards indorsed this as a practical means for progress and was represented on this committee. This work lasted a large portion of the year.

On this committee were represented the American Railway Association, the American Railway Engineering Association, the Railroad and Warehouse Commission of the State of Minnesota, the National Scale Men's Association, the Scale Manufacturers' Association, and the Bureau of Standards. This committee drew up specifications which met the approval of all of the members and embodied features which the Bureau of Standards, as a result of its experience in railroad track scale work, advocated as desirable and necessary.

It is believed that these specifications will be widely adopted and result in a standardization of railroad track scales throughout the United States to the extent that standardization is valuable, and will result in a marked improvement in railroad weighing.

Specifications for Scales for Weighing Grain.

The subject of defining what constitutes proper and adequate facilities for weighing grain has recently assumed large importance, and hearings relating to this matter were held by the Interstate Commerce Commission under docket 9009, dealing with loss and damage claims for grain in bulk shipments. The Bureau of Standards cooperated in trying to solve the difficulties by having a representative on a committee organized for the purpose of drawing up specifications defining what constituted proper facilities for weighing grain. It was neither practical nor possible under the circumstances to make an exhaustive investigation of the matter similar to that which had been carried out by the Bureau for railroad track scales, but tentative specifications were drawn up which represented the best information available on the subject.

These specifications were submitted to the Interstate Commerce Commission, which in turn submitted them to a joint committee representing the shippers and carriers, formed for the purpose of agreeing upon just and practical rules to govern the settlement of loss and damage claims.

If these specifications are accepted by the shippers' and carriers' committee, the Bureau of Standards will probably give them its indorsement and issue them as a circular.

Railroad track scales for weighing grain have been studied by the Bureau in connection with its railroad track-scale testing equipment. Hopper scales and automatic scales are matters on which much work remains to be done before any decision can be reached as to just what equipment and installation is required to secure accurate results, and the best and most economical manner of designing, installing, and using such scales.

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.)

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

On account of the very material increases in the cost of all necessities of life the need of efficient inspection of weights and measures in commercial use is being more and more strongly felt, and several States have recently enacted laws establishing State-wide inspection for the first time. Among these may be especially mentioned Texas, North Dakota, and South Dakota, all of which have established comprehensive laws. Other States have added to their general code on this subject, while still others are conducting investigations to find out what character of legislation is needed. In connection with this activity, the Bureau of Standards is receiving an increased number of requests for assistance in establishing State departments, in conducting field investigations in various localities, in passing upon types of weighing and measuring apparatus to determine its fitness for commercial use, etc. Enormous good would doubtless result from increased activity in these fields of work, but lack of appropriations make it impossible to accede to many requests, even of the greatest urgency.

As a specific instance of the character of assistance requested may be mentioned legislation recently passed in the States of Maine and Texas. In the former State this becomes of force and effect on July 1, 1920, and provides that after that date no weighing and measuring apparatus may be sold in the State which has not been approved by the Bureau of Standards. In the latter State any apparatus approved by the Bureau of Standards may be sold without a special certificate from the State authorities. Unless an appropriation can be obtained for this work it will be impossible for the Bureau to undertake it, since it would be futile to attempt such a task with the present staff and facilities available. As a result, laws designed to protect the merchants and consumers of this State will be nullified. Yet not only would the results of such an investigation be of assistance in the States mentioned, but to all other States as well, many of which would rely upon the Bureau for technical infor- of this kind. Desirable uniformity could thus be brought about.

Other States, among which may be especially mentioned Virginia, desire information as to conditions existing in order that a basis for weights and measures legislation may be obtained. In these cases also the Bureau is often unable to proceed on account of shortage of funds. The need of a special appropriation for carrying on the work of cooperation with the States in weights and measures matters is very urgent.

Representatives of the Bureau attended State conferences of weights and measures officials in Michigan and New York and gave addresses on subjects of interest to the delegates.

Proposed Federal Legislation.

Congress has not enacted any legislation on the subject of weights and measures during the past year. However, the Bureau has been working on a draft of a bill designed to standardize flour, meals, and commercial feeding stuffs throughout the United States, upon the hundredweight basis. This proposition was first brought before Congress last year, and since that time work has been done in perfecting it so that in its present form it has the hearty indorsement of all interests concerned, including the Millers' National Federation, an association comprising the large majority of the flour producers of the country, the American Corn Millers' Federation likewise including a large majority of firms in this industry, and every State association of weights and measures officials where the bill was considered, including New York, Massachusetts, Indiana, Wisconsin, Michigan, and Maine. Briefly, the bill eliminates the 196-pound barrel and the cumbersome and nonuniform subdivisions thereof now standardized in the various States and substitutes in their place the 200-pound barrel, with subdivisions of 100, 50, 25, 10, 5, 4, 2, and 1 pound. If this bill is enacted into law, a long forward step in uniform standardization of packages will be obtained, and some of the most important foodstuffs sold in package form will be efficiently and adequately regulated.

Twelfth Annual Conference on Weights and Measures.

In order to assist the various State and local departments enforcing weights and measures laws throughout the United States in obtaining the greatest uniformity and in maintaining the greatest efficiency in their work, it has been the practice of the Bureau in the past to invite all those officials and others interested to attend a general conference on weights and measures at the Bureau of Standards once in each year. On account of the war these meetings were discontinued in 1917 and 1918, but this year it was deemed advisable to resume them, and consequently the twelfth conference was held on May 21–24, 1919. Great interest was manifested in this meeting. It was more generally attended than ever before, and was in every way a success. About 180 official delegates and visitors attended, 29 States being represented. Perhaps the most important constructive action taken was the tentative adoption of a set of specifications and tolerances for liquid-measuring pumps used in the sale of gasoline. These specifications and tolerances had been prepared by the Bureau of Standards as a result of a comprehensive investigation made shortly before the war. In general, these pumps have not been adequately regulated in the past, and, as a result, short measure in the sale of gasoline has been very common. With a uniform system of specifications and tolerances in use it is believed that much more success will be obtained in coping with the situation. Enormous losses to the consumer can be thus prevented and competition put upon a fair and honest basis.

Resolutions were passed by the conference indorsing legislation empowering the Bureau of Standards to pass upon and approve types of commercial weights and measures and weighing and measuring devices manufactured or offered for sale in the United States; and approving the decimal weight flour bill now pending in Congress. The conference also went on record as favoring the sale of dry commodities by weight; the marking of net weight on wrapped hams, bacon, and other meats; the standardization of packages; and the metric system of weights and measures.

About 15 years ago the Bureau of Standards announced its intention of exercising its functions in such a way as to be of maximum assistance in regulating and improving the general condition of weights and measures in commercial use and the manner of sale of commodities, and as a first step in this direction there was inaugurated the annual conference on weights and measures of the United States. At this meeting the representatives of the States were informed that to accomplish the above end the Bureau would give all necessary assistance in building up State and local inspection departments. In the case of matters of such a nature that they should be administered by the Government, the Bureau would procure and enforce necessary Federal legislation. Finally, the Bureau would act as a general clearing house for weights and measures information and assist in coordinating the activities of the Government and of the various States, so that maximum efficiency of procedure would be obtained.

For some years thereafter the Bureau of Standards was the only Federal agency in this field and completely dominated it. Much valuable progress was made toward obtaining the objects sought. Field investigations were made in every State in the Union, and commercial conditions were thereby determined, a model law was drawn up and its introduction procured in numerous States, Bureau representatives appeared before State legislative committees in support of the legislation proposed, and it was enacted in a large number of States. Following this action Bureau representatives visited these States, helped to establish the departments, drew up tolerances and specifications for commercial apparatus for their guidance which were promptly adopted by a number of States, and did other necessary work along the original lines of cooperation proposed.

During this time, also, the Bureau undertook to procure needed national legislation. The Federal apple-barrel law, the standard-barrel law, and the standard lime-barrel law were enacted by Congress, statutes important in themselves and more important still as a percursor of other legislation to follow. The proposed law for the Federal standardization of type of commercial weighing and measuring apparatus was drawn up and introduced with the hearty approval of the States.

Notwithstanding these activities and achievements, the Bureau is slowly but steadily losing ground in this field, owing to the insufficient funds with which to carry it on.

In the meantime, the Bureau of Markets and the Bureau of Chemistry in the Department of Agriculture, with a corps of agents in the field and ample funds, have taken up this work and are now claiming it as their own field. The efforts of the Bureau have merely been successful in indicating to these bureaus the possibilities in the weights and measures field. They have procured legislation such as the Federal standard container act and are vigorously enforcing it, whereas the standard-barrel laws are entirely unenforced by the Bureau of Standards, due to the lack of funds to put any inspectors in the field to look after it. It is much the same in the case of State cooperation; the Bureau has no representatives in the field, while the Department of Agriculture has numerous traveling inspectors who visit the States and assist the officials on all occasions, even in weights and measures matters. Very recently the Bureau of Markets, under the terms of the Federal warehousing act, issued rules and regulations requiring that scales used shall be of types approved by the Bureau of Markets, a matter which distinctly belongs in the field of the Bureau of Standards.

The time has now come when the Bureau should prepare to go forward vigorously or else to turn over to others the whole practical question of inspection, and with it the related one of commercial standards. If Congress is unwilling to give the Bureau a fund to take care of the laws which it now has to enforce and to enlarge its functions so that the matter can be handled in an adequate and businesslike way, it will be better for the Bureau to withdraw from the field altogether.

The same is true, but to a lesser extent, in the track-scale work of the Bureau. In this it has reached a point where instead of going forward we are losing ground. Its appropriations for this work have not been increased since 1913, when the work was commenced. In addition, it is faced with constantly rising salaries and increased expenses of operation of all kinds, while the demands for tests from the States, Federal agencies, the railroads, and others, are steadily increasing. It was found necessary last year to lay up two of the equipments for months and allow several of the best-trained field men to leave the service on account of the lack of funds. The situation will probably be still worse during the present year. The preliminary work has been done, but conditions have been shown to be extremely bad and in urgent need of competent regulation. New organizations, such as the Eastern Weighing and Inspection Bureau, are being formed to do work which should be done officially. The time has now come in this field also when the Bureau must of necessity go forward and occupy this field of regulation or retire in favor of some organization which will be prepared to do this.

One step needed to strengthen the Bureau's position in this field is the establishment of a depot in Chicago or some other western railroad center. Its present activities are merely successful in showing the necessity of governmental supervision of the scales used in interstate commerce, and there are numerous indications that other agencies are planning to take upon themselves this work. In order to properly handle the situation, the Bureau should have at least a dozen stations strategically located throughout the country. Each of these stations should have a master scale and the necessary test cars and equipment to supervise the test of all track and grain scales in their respective districts. Eventually an appropriation of $500,000 or more may be required. This program can not, of course, be carried out in one or two years, but sooner or later the demands of farmers' organizations and others using railroad track-scale weights will be heeded by Congress, and that agency which occupies the largest part of the field and shows itself most competent to handle the matter will be designated by Congress to do so.

The position of the Bureau in this field is as strong as it is likely to be with its present facilities. As more State organizations are formed and the railroads consolidated the Bureau's position will become relatively weaker. It is therefore strongly recommended that every effort be made to secure the appropriation for the depot asked for last year and again this year without success.

Routine Testing.

The routine testing in section 1, length; section 2, mass; and section 4, volumetric, of this division is from three to six months behind. This condition is due to the fact that for some reason, probably the recognition of the commercial importance of technical and scientific work brought about through the war, an increase has resulted in the use of certified apparatus of the kind handled by the sections mentioned above. Every effort has been made by those engaged in this work to promptly dispose of it, but it has been beyond their capacity. As the work is now conducted it only creates dissatisfaction and brings severe criticism upon the Bureau and its employees, which is unwarranted, as important research work has been abandoned to care for routine tests. Not only are needed researches and investigations halted, but the testing is not done with that care which should characterize all of the work of the Bureau.

The Bureau has issued circulars giving the fees, and has been doing this work for a number of years. It has educated the public as to the importance of using apparatus that has been certified by a competent authoritative agency, and it should continue to do this work so essential to American industries, if it can be done with credit to the Bureau, or at least without discredit.

If Congress does not deem it proper to provide for this work for which estimates will be submitted, it would be well to consider the proposition of placing it on a self-supporting basis. It is hoped, however, that this need not be done, since such a plan has many disadvantages and often leads to embarrassing circumstances.

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 standardization, including standards of adequacy, and safety of 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 electrical measurements 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 apparatus and materials. 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 materials furnished upon them.

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. Much 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 on correlation of magnetic and mechanical properties of iron and steel and in the 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 first half of the year the demands for service to military departments were so numerous both in testing and in research that the resources of the electrical division, like those of other parts of the Bureau, were very largely devoted to such service. This involved an increased amount of work similar to that performed in ordinary times, including consultation with other departments on a larger number of technical problems. Extensive experimental investigations of a few important military problems begun during the preceding year were also actively continued.

Since the cessation of hostilities attention has naturally been turned to the revival of the normal work of the Bureau, but a large amount of time has been required to bring the military work to a satisfactory conclusion and to put the results in such form that the labor already expended should not be lost. Furthermore, many of the investigations begun on account of military needs are equally important in times of peace, and even equipment specifically developed for military use has in some cases been found applicable to industrial needs. These considerations have made it appear inadvisable to cut off immediately the activities which arose from the war, and it is hoped that means will be found to continue permanently some of the more important of these activities without sacrificing the fundamental work in electrical research previously carried on.

Standardization of Electrical Equipment and Supplies for the War Department.

In order to simplify the handling of purchases of equipment and supplies for the War Department, the Standardization Section of the Purchase, Storage, and Traffic Division, General Staff, in August, 1918, appointed a committee on standardization, consisting of one member from each bureau of the War Department and one from the Bureau of Standards. This general representative of the Bureau was designated from the electrical division; and while some subcommittees of the general committee on standardization dealt with supplies of other kinds and called on many sections of the Bureau for information and assistance, the most active work was done in cooperation with the various subcommittees on electrical supplies. To this work three members of the Bureau staff gave practically all their time for several months, while a number of others contributed materially to the work of committees in their special fields.

Through the activities of the Bureau representatives the standardization committee was brought into touch with war-service committees of the various branches of the electrical industry, and a plan of discussion of proposed schedules and specifications was adopted which gave all interests concerned an opportunity to present their views to the committee. A close-working connection with the subcommittees of the standards committee of the American Institute of Electrical Engineers was also established through the Bureau's representation on that committee, and their assistance was obtained in the preparation of a considerable number of specifications for apparatus and material.

A considerable amount of testing was also required in connection with this work. Some of this was of routine nature as regularly carried on by the various sections of the electrical division, but other tests constituted rather extensive investigations, such as those on trucks and tractors and the storage batteries used in such vehicles and on protective lighting equipment. These are described later under the appropriate sections.

The results of all this standardization work were incorporated in a catalogue of supplies for War Department purchases which has been issued by that department. In several fields the work done emphasized the need of further extensive investigations, and the Bureau has been specifically requested to undertake investigations on miniature electric lamps, transformers, electric fans, storage batteries, stranding of cables, and insulation problems in connection with rubber-covered wires and cables, which would involve a large increase in its work in all these fields. Some of these investigations it is planned to undertake, but the adequate handling of most of them must await an increase in the resources available for the work.

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, galvonometer design.)

With the exception of necessary work in routine testing of apparatus and materials, this section has given all its time during the past year to special problems arising from the war, the more important of which are described below.

Nondestructive Tests of Welds.

Some method by which the quality of welds, especially welds in ship plates, may be determined without the destruction of the weld has been very much needed. It has been suggested that if the electrical resistance of such welds could be measured it would give an indication of the quality of the weld without destroying it. Such measurements, however, were considered impracticable, if not impossible.

An investigation was made which showed that with a current and potential terminal on either side of the weld and all four terminals fairly close together the resistance of a small portion of the plate, including a part of the weld, could be determined rather easily with the accuracy required. For example, a saw cut extending a quarter of the way through a half-inch plate could be easily detected by this means from either side of the plate. However, it appears that plates poorly welded may make excellent electrical connection with each other, and consequently the resistance method is not successful as a means of determining the quality of such welds.

Control of Airplane Guns.

At the request of the Division of Military Aeronautics and the Inventions Section of the General Staff, this section of the Bureau undertook an investigation of the possibility of using electrical means for the control of airplane guns which must shoot between the blades of the propellers. The time between successive passages of the propeller blades through the same position is about 0.02 second. It is, therefore, necessary that the shots be timed with respect to the time of passage of the blades through the line of fire to better than 0.02 second. That is, the control apparatus must perform its function, the firing mechanism of the gun must operate, the primer explode, the charge explode, and the projectile pass through the barrel and past the propeller in less than 0.02 second if the apparatus is to operate at all speeds without compensation for changes in speed.

An electrical-control apparatus was developed which performs its function in a few thousandths of a second, so that the over-all time of action, up to the passage of the projectile 4 feet beyond the muzzle of the gun, is about 0.01 second. This type of gun control has many advantages over the mechanical and hydraulic types generally used, and further development incidental to its use with various types of gun is being carried out by the Division of Military Aeronautics with the cooperation of the Bureau.

Action of Browning Field Gun.

At the request of the Ordnance Department of the Army, an investigation of the action of the Browning field gun was made for the purpose of finding out whether faulty action of the reciprocating parts was responsible for excessive breakage of the casing which was found to occur in service. The relative positions of the three principal reciprocating parts were determined throughout their cycles of operation, both when the gun was operated by hand and when it was firing. The results obtained showed that throughout the cycle each of these parts remained in a proper position with respect to the others and that consequently their action was presumably not the cause of the breakage. The methods used in this investigation were largely electrical and involved the services of electrical experts.

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.)

Inductance and Capacity Laboratory.

With the exception of necessary work in routine testing, this section has devoted practically all its time during this year to military problems. The amount of testing has increased considerably, especially during the latter half of the year.

The development of formulas for the alternating-current resistance and inductance of a "return circuit" has been completed, and the formulas have been applied to experimental results obtained by others, showing good agreement. A paper giving the derivation of the formulas and a discussion of the results has been prepared for publication under the title, "An Integration Method of Deriving the Alternating-Current Resistance and Inductance of Conductors."

Measurements of the resistance and inductance of a "return circuit" composed of No. 2 copper wire have also been made in the laboratory at frequencies of 500, 1,000, 2,000, and 3,000 cycles per second, and the measured values agree very well with those calculated by the formulas.

Gun-Firing Investigations.

The gun-firing investigations which this section undertook for the Bureau of Ordnance, Navy Department, some time ago have been continued throughout the year, and the scope of the work has been broadened until now it covers a large part of the field of ballistics. A study of the work that has been done by others along similar lines indicates that the section has collected a larger amount of data concerning the behavior of certain types of guns than has been collected heretofore. The chief investigations which are being carried on by the section at the present time are listed below.

Theoretical Study of the Motion of a Projectile.—Prof. H. C. Richards of the Physics Department of the University of Pennsylvania spent the summer of 1918 at the Bureau studying the theory of the flight of a rotating projectile. He consulted all available literature and attempted to reconcile the theories with the experimental data available. Dr. Richards has continued his interest in this subject throughout the year and is preparing a report of his work.

Study of Variations of Gun Pressures with Time.—Data obtained during the experimental firing on naval vessels indicated the need of a time-pressure gauge. An experimental gauge was designed and built at the Bureau during the summer and fall of 1918. It was tested by placing it in a bomb in which a small charge of powder was exploded. As these experimental tests gave very promising results, the Bureau of Ordnance ordered five gauges made for use in certain of the naval guns. These gauges have been completed and are now being given the final tests at the Bureau. Recently the Ordnance Department of the Army requested the use of these gauges in their work.

Primer-Explosion Times.—In the work during the previous year on electric cannon primers it was assumed that the breaking of the platinum bridge wire indicated the explosion of the primer. Subsequent experiments, however, showed that this was not always the case. An additional investigation was, therefore, carried on in which the time of the explosion of the primer was taken as the time at which a fuse wire placed in front of the primer was broken by the flame. A number of makes of primers were used in the investigation. It was noted that the older primers were slower in firing than those of recent manufacture. The Bureau of Ordnance has requested that the investigation be continued, using a large number of primers of as many different "ages" as possible.

Ejection Velocities.—In the study of factors which may cause dispersion of fire there is need for a method by which the muzzle velocity of each projectile fired from the ship can be measured. Considerable time during the past year has been spent in the study of this subject, and a method has been developed by which the "ejection velocity" of a projectile may be determined on shipboard with an accuracy of approximately 1 per cent. The velocities so obtained are designated as "ejection velocities," since they differ slightly from those usually defined as "muzzle velocities."

Study of Recoil.—Recoilmeters have been built which, in connection with the oscillograph, record the time at which the gun passes certain predetermined points in its recoil and counterrecoil. From these data a space-time recoil curve can be plotted. By successive graphical differentiation of the space-time recoil curve, velocity-time and acceleration-time curves may be obtained. Theoretically these curves should furnish information regarding the velocity of the shell inside the bore of the gun and the variation of powder pressures within the gun chamber. Results so obtained, however, do not agree with those obtained from the theory of internal ballistics and indicate that this theory is not as well known as it should be. The study of the recoil also gives information concerning the forces which the gun mountings must withstand during the recoil of the gun.

Firing-Time Intervals.—A study of the firing-time intervals which occur during the firing of the gun has been continued in cooperation with the Navy during the year at Indian Head and aboard ship. The chief items of interest to be noted in this work are that the powder interval—that is, the interval which elapses after the primer explodes and before the gun begins to recoil—varies largely for different shots, and that the barrel time—that is, the time after the beginning of recoil until the ejection of the shell—is a function of the gun and its mounting.

Jump and Whip of Guns.—Kinemeters, which have been used in experimental firing, have been constructed for the Navy and measure the jump and whip of a gun at the instant it fires.

Velocity Inside Bore of Gun.—During the latter part of the year the Coast Artillery has been cooperating with the Bureau in the design of apparatus for determining the velocity of the shell as it moves through the bore of the gun. This apparatus is now being completed in the shops of the Bureau.

Velocity Measurements by Means of Magnetic Effect of Projectiles.—In the past a number of attempts have been made to determine the velocity of a projectile by shooting it through coils of wire and using the current induced in the coil to determine the time at which the shell passed through the coil. In general, these attempts have not been successful on account of a lack of knowledge of the fundamental physical effects which are involved.

At the request of the technical staff of the Army, this Bureau has undertaken an investigation of the possibilities of this method. It is proposed to study particularly the relation between the phase of the induced current and the position of velocity of the shell.

Blast Investigations.—Throughout the year the Bureau has continued the measurement of the characteristics of the blast of large guns for the Navy, but since other lines of work have seemed more urgent this work has not progressed as rapidly as was desired. An electromagnetic blast meter has been designed and built, and preliminary tests are being made at the Bureau preparatory to testing it under service conditions at Indian Head Proving Ground.

Timing Device.

In the study of the method of determining ejection velocities, a special timing device, with which an electrical oscillograph may be equipped, has been developed. Tests of this device show that by its use time intervals may be determined to an accuracy of a few millionths of a second. While the method was developed for a particular purpose, it is applicable to the measurement of any small time interval which it is possible to record electrically.

Submarine-Mine Investigations.

Improvement of Mine Detonators.—At the request of the same bureau, the study of possible improvements in a special type of mine detonator was undertaken late in the year.

Protection of Ships Against Mines.—At the request of the Navy Department, one of the representatives of the Bureau, while in England, visited the mine-sweeping fleet to make some experiments on a method which was in use for the electrical protection of the mine sweepers engaged in the removal of the North Sea mine barrage. A satisfactory method of protecting the ships themselves had been devised, and it was desired to extend the method so as to protect the sweep wires also. Difficulties inherent in the method made this extension impracticable.

Hydraulic Machine-Gun Synchronizing Gear for Airplanes.

At the request of the War Department, a detailed study was made of the factors which are of importance in hydraulic methods of synchronizing machine-gun fire in airplanes. In this work it was shown that there is an appreciable time interval required for the transmission of the energizing pulse in the tube of liquid which is used to fire the gun. The fact that such a time interval is unavoidable in any hydraulic or other mechanical control system limits the application of such devices and is a strong argument for using an electrical system such as that mentioned above, in which the time required for the action of the control gun itself can be made very small.

Special Muzzle-Velocity Measurements.

At the request of the Army, measurements were made of the velocity of bullets fired by centrifugal guns which were under test at the Bureau. The measured velocity agreed quite closely with the theoretical velocity. Measurements were also made of the muzzle velocity of a captured German automatic antiaircraft gun of 2-centimeter bore, using regular German service ammunition.

Study of Recent Scientific Developments in France and England.

The chief of the section spent April, May, and June, 1919, in France and England studying scientific developments which have occurred during the war, especially the improvements in ballistic instruments. Both the Army and the Navy cooperated heartily; they extended every courtesy and in many ways showed their appreciation of the studies which were being undertaken. All of the important scientific laboratories doing research work along ballistic lines were vistited. In addition many observations of general scientific interest were made. A report covering this trip is in preparation.

ELECTRICAL MEASURING INSTRUMENTS.

(Testing and development of electrical instruments, meters, and ignition apparatus.)

Testing of Electrical Instruments.

The volume of testing for outside parties was very much reduced by the war, but the testing for Government departments was greatly increased, so that the total number of instruments tested was larger than in previous years.

The testing of instrument transformers had to be discontinued during the war because of the departure from the Bureau of members of the staff who had previously been engaged in this work. This class of testing has been resumed in the last few months. The accurate testing of these 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 and the Bureau has consequently given special attention to the development of methods and equipment for testing them.

Electrical Tests of Gasoline-Engine Ignition Systems.

The demand for routine tests of ignition apparatus reached a maximum last autumn and has since decreased, but requests for tests are still being received from manufacturers at the rate of about four per month.

The investigational work on spark plugs as first planned has been completed except for measurements of temperature conditions in aircraft engines. This latter work has been held up for lack of both staff and available engines. The porcelain developed by the Bureau is now in regular production by the largest spark plug manufacturer in the country.

The use of a subsidiary gap in series with a spark plug was studied experimentally, and a preliminary report has been issued showing the advantages and disadvantages of this device.

Considerable study, both theoretical and experimental, has been made of the operation of the high-tension magneto with a view to developing a working theory on which to base a logical design of such apparatus. Particular attention is being paid to the effect of secondary capacity and eddy currents, and methods are being developed to measure these effects quantitatively.

A series of 15 reports have been issued covering various phases of the ignition work. These reports will be printed in the Fourth Annual Report of the National Advisory Committee for Aeronautics.

At the request of the Motor Transport Corps specifications for spark plugs have been prepared to serve as a basis for their purchase.

Considerable time has been spent in cooperation with the areonautic engine-design section in developing a method for measuring the velocity of flame propagation in the cylinders of internal-combustion engines. This method, which records the time of passage of the flame oscillographically, gives good promise of success and an extensive program of work has been laid out for it.

Electrical Trucks and Tractors.

At the request of the War Department, the Bureau cooperated in comparative tests of a large variety of electrical trucks and tractors for use in Army warehouses. The records of these tests were worked up and reports issued by the Bureau on the basis of which the Purchase, Storage, and Traffic Division has prepared specifications for the purchase of such equipment.

Turret Fire-Control Apparatus.

A study of the electrical target turret indicators used in controlling the fire of battleship turret guns was begun last year in an attempt to find the causes of errors which sometimes occurred in the indication of the apparatus. This investigation was continued this year, and after a thorough study of the operation of the apparatus at various speeds, changes in the equipment, which it was believed would remedy the defects, were suggested to the Navy Department and to the makers of the apparatus.

Blasting Caps.

At the request of the Engineer Corps, a study was made of the time required to fire electrical blasting caps used in setting off mines, gas projectiles, etc., with a view to determining the possibilities of firing a number of such caps in series. About one hundred caps were fired under various conditions and the time recorded by the oscillograph.

The study of blasting machines mentioned in last year's report has led to the development of a new type of machine having over 10 times the capacity of the older type and slightly less cost and weight.

Radio Generators.

Considerable time was spent in planning and supervising tests of 900-cycle generators for use in airplane radio sets. The work consisted in obtaining characteristic curves, efficiencies, etc., of a number of generators under various conditions. The observations were made by enlisted men of the Signal Corps, but the planning of the work and preparation of reports was under the direction of the Bureau.

Cooperation with American Institute of Electrical Engineers.

At the request of the Instruments and Measurements Committee of the American Institute of Electrical Engineers, the preparation of an exhaustive paper on "The accuracy of Commercial Electrical Measurements" has been undertaken. This work is well under way, and the paper will probably be delivered at the institute meeting in the autumn. A considerable amount of time has also been given to assisting in the revision of the American Institute of Electrical Engineers Standardization Rules, and many errors and inconsistencies in the older edition have been eliminated.

New Apparatus for Electrical Instrument Testing.

An attachment is being developed for use with the deflection potentiometer which serves to plot automatically the corrections of the instrument under test, thus avoiding all numerical computations. When a set of standard shunts designed to accompany this has been built, the time required in instrument testing will be materially reduced.

A new form of variable resistence has been constructed for use in testing current transformers and is now ready for final adjustment.

The use of this will reduce the labor of such tests by at least 30 per cent.

Ignition of Cotton by Electric Sparks.

At the request of the Department of Agriculture some experiments were made on the ignition of cotton by electric sparks and on the generation of electrostatic charge by the passage of cotton through iron tubes. This request was occasioned by the frequent fires which occur in cotton gins apparently as a result of static discharges. The results obtained indicate that this is a very real fire hazard and that the fire risk in gins can be materially reduced by proper electrical grounding of the metal parts of the machinery.

MAGNETIC MEASUREMENTS.

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

General Magnetic Measurements.

In addition to the routine testing of the magnetic properties of materials, the work of the section includes the experimental study of various methods and instruments for making magnetic measurements. Such a study is nearly completed on a new type of permeameter (the Fahy Simplex), which has recently been put upon the market. The results so far obtained indicate that the instrument is convenient and rapid and has an accuracy which is satisfactory for most commercial and research purposes. The instrument requires only a single specimen, and there are no compensating adjustments to make.

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. The results of this work and the growing interest of manufacturers of steel products justify a systematic general study of the subject for the purpose of determining to what extent magnetic analysis can be utilized both in research and for practical testing on a commercial basis. The method promises to be very useful for the detection of inhomogeneities and flaws, for the detection and study of physical and chemical transformations which take place in iron or steel on heating or cooling, and for the estimation of the physical condition and the prediction of mechanical behavior of steel and steel products.

During the past year a comprehensive program has been started which consists of three distinct though closely interrelated parts:

I. Study of the fundamental relationships between the magnetic properties and the physical structure and mechanical properties of various types of steel by means of accurate magnetic and mechanical tests on specially prepared samples.

II. Development of special apparatus and methods for making magnetic tests on various forms of steel objects.

III. Development of a number of direct practical applications for the purpose of demonstration.

In this work the magnetic section has the cooperation of a number of commercial organizations as well as of other sections of the Bureau.

Rifle-Barrel Steel.—An investigation has been completed and a paper is in press on "The Testing of Rifle-Barrel Steel for the Detection of Flaws." This investigation was made in cooperation with a large manufacturer of rifles. The results of the work indicate that the magnetic method will surely detect flaws, but that other causes may render the material nonhomogeneous along its length when it is not necessarily unfit for use. In view of this fact it seemed desirable to study further the possibilities and limitations of the magnetic method, and in this work the Bureau has the valuable cooperation of the Technical Staff of the Ordnance Department. The construction of special apparatus for this investigation is under way.

Ball-Bearing Races.—The development of a magnetic method for the testing of ball-bearing races which was interrupted during the war has been resumed in cooperation with one of the large manufacturers of ball bearings. It is proposed, if possible, to develop a method which will be commercially practicable for the determination of hardness and the detection of cracks or soft spots.

Correlation of Properties.—An investigation has been started for the correlation of the magnetic properties with the micrographic structure and mechanical properties of a carbon steel of eutectoid composition. Accurate tests will be made on standard test pieces after various heat treatments. Information of this kind is fundamental to the development of magnetic analysis and the investigation will be extended to include the study of various types of steel.

Miscellaneous Problems.—In addition to the above investigations a number of less-extended experiments have been made to ascertain the applicability of magnetic analysis for the inspection of various articles, including welded ship plates, airplane tie wire, and rifle-barrel forgings. Most of this work was not completed owing to the fact that with the ending of the war the necessary funds and facilities were no longer available.

Magnetic Compasses.

Most of the work on magnetic compasses during the year consisted of cooperation with various branches of the military service. In addition to work on testing of airplane compasses, which consisted of testing a small number of instruments for the purpose of checking the field inspection, a number of special investigations were made covering various points of compass construction. These investigations included the development of a suitable process for aging compass magnets and a test for aging, a study of the relative merits of platinum and stellite for pivots, and a study of the relative behavior of natural and artificial jewels for pocket compasses.

A collection of a number of types of airplane compasses which will be valuable for further study has been made.

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.)

Military Searchlight Investigations.

On account of the importance of searchlights in modern warfare and the need of more knowledge of their characteristics and performance, the Searchlight Engineering Section of the Four Hundred and Eighty-eighth Engineers requested the Bureau to cooperate with them in the investigation and testing of searchlights. The work was begun in March, 1918, and continued until January, 1919. The investigations included the following:

Distribution of Light from the Bare Arcs.—Light distribution in several planes through the arcs without mirrors was measured in the laboratory. Seventeen arcs of various types and conditions were measured in this manner. From these measurements information was obtained as to their effectiveness in various searchlight mechanisms. The tests were also useful in giving data for specifications for searchlight carbons.

Distribution of Light in the Searchlight Beam at Various Distances.—A great many tests were made to determine the distribution of illumination in the beam. The most of the tests were made at a distance of 930 feet, 20 lamps being so measured. In addition, other measurements were made at various distances up to 5 miles.

Absorption of Light by Front Glass of the Searchlight.—A number of tests were made to determine the amount of light lost by absorption, reflection, and scattering of light by the front glass, and by devices for limiting the beam and avoiding stray light.

Photometric and Illumination Investigations for Military Departments.

Daylight Signaling Devices and Special Lamps.—A great deal of time was spent in a study of daylight signaling lamps and lamps for signaling from airplanes at night, this work being undertaken at the request of the Bureau of Aircraft Production. Daylight signaling tests were carried out over ranges of one-half, 2, 3 and 5 miles to determine the magnitude of the intensities required. Many tests were also made to determine the increase in beam efficiency due to partial silvering of lamp bulbs used in the signaling devices.

Protective Fence Lighting.—In September, 1918, the Bureau was requested to make a comparative test of various floodlight projectors for protective fence lighting. The tests were carried out with the cooperation of the Ordnance Department and resulted in the recommendation of the use of angle reflectors throwing the light at right angles to the fence instead of floodlights throwing the light parallel to the fence, as the tests showed that the smaller reflectors were superior to floodlights for the type of service required. The signing of the armistice stopped purchases of such equipment, but the results of this investigation will be of assistance in the future design of protective lighting installations.

Acetylene Generators.—Last year several months were spent in an investigation of the performance of numerous types of portable acetylene lights, with particular reference to their suitability for military use at the front. This investigation was originally intended simply to give information on which a choice between the various types of lights could be based, but it developed that many of them had certain features which made them unsuitable for use under the prescribed conditions. Consequently the makers were consulted, and a number of modifications suggested by the Bureau were made in the lights.

During the present year, as a result of a controversy over the merits of one of the lights recommended as a result of the above investigation in comparison with a new type developed for Army use, further investigation was requested, and extensive tests were carried out, particularly to determine the reliability of operation of the lights. The results obtained fully confirmed the earlier recommendations of the Bureau.

Miscellaneous Tests.—In addition to the special investigations outlined above, numerous acceptance tests of kerosene and signal oils, reflectors, luminous flares, star shells, etc., were made. To assist military departments in the design of instruments and apparatus many lamps were photometered and illumination instruments calibrated.

Standardization of Screens for Measurement of Brightness of Radioactive Materials.

The measurement of the absolute brightness of radioactive, self-luminous materials has become commercially important because of the greatly increased use of such materials in recent years. This work is handled by another section (see report below) but the photometry section has been called on for the calibration of colored screens which are used to make the light from electric lamps comparable in color and intensity with the luminous materials. Such screens have been standardized for the Bureau of Mines as well as for this Bureau.

Inspection and Life Tests of Incandescent Lamps.

Orders for about 4,225,000 incandescent electric lamps were placed by departments of the Government during the year. Of this quantity about 75 per cent were large tungsten, 13 per cent carbon, and 12 per cent miniature lamps. Six per cent of this total were ordered shipped without inspection, whereas during the previous year about 20 per cent were so ordered from a quantity approximately twice as great. Actual inspections by this Bureau during the year, including lamps delivered on orders last year, approximated 5,100,000, of which about 4,000,000 were large tungsten, and the remainder carbon and miniature lamps in about equal quantities. This represents an increase of about 40 per cent in inspection over last year.

The initial inspection made at the factories covers the mechanical qualities of the lamps and their rating with regard to power consumption and efficiency. In order to pass a final judgment on the quality of the lamps it is necessary to have actual burning tests, and when the initial inspection is made samples are selected for such tests, which are called " life tests." During the year life tests were completed on 2,683 vacuum tungsten, 152 gas-filled, and 373 carbon lamps. Records of these tests were kept separate for each month of manufacture in order to compare results with those obtained in current tests of the product made at the factories. It was found that gas-filled lamps, which are now included in the standard specifications, considerably exceeded the life requirement, and, following the usual practice, one of the large manufacturers has improved efficiencies to take up a great part of this excess life. Efficiencies of vacuum tungsten lamps are also undergoing a gradual improvement.

Work of considerable importance was done by special inspections and tests of lamps for the General Supply Committee in connection with bids for supplying lamps under contract for the fiscal year 1920; data regarding the quality of lamps which some of the new bidders proposed to furnish were obtained as a result of these tests, and served to guide the Supply Committee in placing the new contracts.

While the specifications for large lamps are in a very satisfactory form, and the efficiency and performance of these lamps are well established, there is little available information with regard to the general commercial quality of miniature lamps such as are used in flashlights and in automobile and similar lighting equipment. As a part of the standardization work in which the Bureau assisted the War Department during the year, tentative specifications for some types of miniature lamps were drawn up and agreed upon with representatives of the manufacturers, but on account of the lack of information as to the limits which could reasonably be fixed for efficiency and life of such lamps the specifications could not be made very strict. Apparatus for making life tests of miniature lamps has now been designed, and the component parts have been purchased. It is expected that this equipment will be installed in time to carry on regular tests on the lamps bought on Government contract during the coming year.

Illumination Surveys of Commerce Department Buildings.

At the request of the Secretary of Commerce an illumination survey of the main building of the Department of Commerce was made. The average illumination in the offices was found to be about 2.5 foot-candles, which is considered the lowest allowable intensity for office work. It was shown that the existing level of illumination could be maintained by substituting more efficient lamps of a lower wattage, making the connected load 30 per cent less, or that the substitution of more efficient lamps of equal wattage would make the intensity about 4 foot-candles, a value more in conformity with good practice.

Some surveys were made in the Coast and Geodetic Survey building and advice given for the material improvement of the lighting in certain special cases. Pressure of other work has prevented a complete analysis of the lighting of all Commerce Department buildings, although preliminary inspection shows that there is room for improvement in several of them.

RADIO COMMUNICATION.

(Maintenance of standards and development of methods of measurement at radio frequencies; investigation, standardization, and improvement of instruments and methods of radio communication; investigation of the properties and uses of vacuum tubes.)

Development of Radio Work of Bureau.

There has been a great expansion of the work of the radio section during this year. The section moved into its new building in October. This change was made the occasion of increasing the equipment and establishing permanent set-ups for testing and for other work involving measurements of a more or less routine nature. The research program has been largely prepared with a view to cooperation with the Signal Corps and Navy Department. For the period of January to June of this year the investigations have been almost entirely work that was undertaken for the Signal Corps.

During the summer of 1918 the section was fortunate in obtaining the services of a number of men of special qualifications from various universities and technical schools who assisted most effectively, particularly in the preparation of the radio textbook mentioned below. For special work of other kinds the section had the advantage of the services of a number of soldiers detailed by the War Department, assisting particularly in the work on vacuum tubes, oscillographic measurements, and testing.

The work of the section is developing into the general field of electrical communication. The methods and instruments of high and low frequency communication are coming to have much in common, and the future promises much in the way of the utilization of the intermediate frequencies which have hitherto been little used. This development is largely due to the vacuum tube and the general study of high-frequency measurements.

Electron Tubes.

An investigation of three-electrode vacuum tubes or electron tubes has been undertaken on a considerable scale. The first work in this field was vacuum-tube standardization for the Signal Corps. Later a number of specific problems in this field were undertaken for the Signal Corps and the Navy. The work has been furthered by conferences held at the Navy Department between the Government departments concerned and the manufacturers of the tubes.

Apparatus and methods have been developed to determine the principal constants and to study the uses of electron tubes as generators, detectors, amplifiers, and modulators. The principles involved in the functioning of these tubes have been studied; for example, one piece of work has been a theoretical study, verified by experiment, of the calculation of the constants of tubes from their dimensions. A critical study has been made of the Signal Corps testing sets for measurements upon electron tubes, and improvements in the sets have been suggested.

Special study has been given to the subject of tubes for generating alternating currents, commonly called "power" tubes. The investigation has had the very satisfactory result of developing a method for calculating the power output from the characteristics of the tubes. This investigation also included a study of the harmonics in power-tube circuits, in typical cases. The dependence of the harmonics on the resistance and reactance of the high-frequency circuit has been determined, and means of calculating the harmonics of the high-frequency current from the form of the pulsating-plate current have been devised. The use of large power tubes has been studied, one of the principal problems being the development of a source of the direct voltage needed for supplying power to the tubes. The use of the large tubes as amplifiers has also been studied. This work has direct applications to the development of practical systems of radiotelephony.

The detector action of electron tubes has been made the subject of a special research. Methods and apparatus for measurement of the detector action have been developed. The detector sensitivity of typical tubes has been measured under varying conditions, and the theory of detector action has been worked out.

A considerable contribution to the fundamental design of amplifiers was made in an investigation of the input impedance of electron tubes. The Signal Corps had found in practice that the constants of the output or plate circuit of a tube affect the apparent input impedance. This complicated the design of amplifiers in which tubes fed successively into one another, and, in fact, made the prediction of performance of any given amplifier circuit practically impossible. The solution to this problem of the effect of the constants in the output circuit on the input impedance was worked out theoretically, and a very satisfactory experimental verification was obtained. This work greatly facilitates the design of amplifiers and gives a better understanding of the operation of electron tubes.

Coil Aerials.

Experiments have been continued on the development of the coil as an aerial in place of the ordinary antenna. Methods of measuring received current were devised and experiments made to check transmission formulas and to assist in determining the fundamentals of design of such coils. A detailed study was made of the resistance of coils and methods of measurement thereof, and the results of measurements of resistance and other constants were coordinated with the results of transmission experiments. These experiments were made on coils of varying dimensions, numbers of turns, etc.

A general paper was prepared on the principles of this subject, discussing the nature of electric waves and radio transmission and reception, giving transmission formulas for either antenna or coil aerials, and discussing the fundamental principles of design and measurement of the antenna effect in coil aerials and of radiation resistance.

A study was made of the accuracy of determination of direction with a direction finder as affected by various kinds of objects in the vicinity. With nonmetallic bodies, such as a tree, a brook, or a bank of earth, the distortion or change in observed direction became negligible at a distance equal to the largest dimension of the object. With objects constructed in whole or in part of metal, such as a bridge, water tower, or the Washington Monument, the distortions were very large and changed greatly with wave length. It was concluded from the experiments that a direction finder must be kept at least 300 feet away from such objects.

An apparatus for determining the absolute direction, as well as line of direction of a radio wave, was developed. The device utilizes the capacity of the coil structure to ground, an inductance in series with this capacity being tuned to the same frequency as the coil circuit. Field experiments showed that the device determines absolute direction satisfactorily. It is, however, somewhat difficult to use, since, like other similar methods which have been developed for unidirectional observations, it requires sensitive adjustments.

Signaling System for Airplane Landing.

Experiments originally requested by the Air Mail Service of the Post Office Department have been in progress to develop a method to enable an airplane to find its landing place in fog or in the dark. The Signal Corps has recently taken an interest in this problem, and the method may be of use for Signal Corps purposes. The object in view has been attained by two general methods. In both a large coil is wound on the landing field and a receiving coil is placed on the wings of the airplane. In one method low-frequency current of 500 or 1,000 cycles per second is passed through the coil. In the other radio-frequency current is used in the coil. By these methods it has been possible to receive signals with an airplane 6,000 feet in the air. The system has the desired characteristic that the signal falls off rapidly as the landing field is left. The transmitting coils used have varied from a size 80 by 200 feet to a size 1,400 by 2,500 feet. A large amount of experimentation has been necessary to determine the proper constants of the transmitting and receiving systems and to determine the characteristics of the method at the various frequencies tried.

Submarine Radio Communication.

Satisfactory methods for communicating with submerged submarines have been urgently needed, and two members of the Bureau staff spent several months during the summer of 1918 at the New London submarine base developing the application of coil aerials for this purpose. Very satisfactory results were obtained. With a single-turn coil or loop attached to the outside of the submarine, signals could be received as well when the submarine was submerged as when on the surface. It was also possible to transmit from a submerged submarine a distance of 12 miles. It thus becomes possible for a ship and submarine to exchange recognition signals. A coil aerial is a satisfactory direction finder when submerged and readily receives signals transmitted thousands of miles just the same as when used in air. The Navy Department considers this the best work which has been done on submarine radio and has equipped the larger submarines with the apparatus which was developed by the Bureau's experimenters.

Insulating Materials.

The investigation of insulating materials carried on this year has been limited mainly to the laminated materials of the phenol or bakelite type, such as are used extensively in making electrical, and particularly radio, apparatus. The electrical properties measured are power loss and dielectric constant at radio frequencies, flash-over voltage and volume, and surface resistivity. The tests of mechanical properties which were made in other sections of the Bureau and for which the samples were cut and the work given general supervision by this section included tensile and transverse strength, hardness, brittleness, permanent distortion, thermal expansivity, density, and moisture absorption. Methods of measuring the effects of high voltages at radio frequencies on the materials were developed. The methods of measuring power loss or phase difference at radio frequencies were improved and a cabinet generating set especially adapted to this work was constructed. Minor improvements were made in the methods of measurement of various properties. The results of measurements indicate, in general, that these materials are susceptible of improvements and that the product of a particular manufacturer varies more from time to time than the products of the several manufacturers differ from one another. The manufacturers and some of the users of these materials have shown an unusual interest in the investigation, and there is every prospect that this investigation will constitute an interesting line of research for some time to come.

Radio Measurements.

High-frequency oscillographic equipment has been developed. Three cathode-ray tubes were constructed and the auxiliary pumps, ovens, etc., provided. One of the tubes is of the hot-cathode type, having movable electrodes, so that a most efficient design can be determined. The equipment has been applied to demonstrations of the steadiness of vacuum-tube generators, to the testing of quenched gap transmitters, and to research on generating vacuum tubes.

A study was made of the production, measurement, and utilization of high voltage and large current at radio frequencies. A vacuum-tube equipment, consisting of six large power tubes, was developed for this purpose. A voltage of 48,000 volts at radio frequencies may be applied to samples of insulating material, and currents of 100 amperes at radio frequencies may be produced for the testing of ammeters. A study has been made of the measurement of radio frequency resistance. A variable resistor for radio frequencies was developed, a study of the precision of measurement made, and sources of error investigated. The study of resistance measurement at radio frequencies is particularly important, since such measurement gives the means of determining a number of quantities, as, for instance, wave form and power.

An investigation was made to determine whether a crystal detector could be developed having a permanent contact. The methods tried in the effort to secure a sensitive, permanent contact detector included alternating-current electrolysis, cathode sputtering, direct-current electrolysis, soldering, arcing, spark welding, and mechanically maintained contact. The latter method gave a thoroughly satisfactory detector, but the general conclusion of the investigation was that the sensitiveness of the best crystal detectors depends upon the existence of an imperfect contact.

The use of a grounded shield in connection with measuring circuits was developed. There has heretofore been no method of protecting the complete radio circuit from troublesome stray electromotive forces, in the way that, for instance, a condenser is protected by its shield. It was found that a shield in the form of a grid of wires between the generating and measuring circuits improved the steadiness of the deflection and the precision of measurement a very great deal. A shielded cage for the inductance coil of the measuring circuit was also developed, so that the entire circuit can be thoroughly shielded.

Radio Textbook.

One of the principal accomplishments of the year was the production of a general textbook to be used in training engineers and operators in the fundamental principles of radio communication. The publication of Circular 74, "Radio Instruments and Measurements," and the furnishing by the Bureau of additional material for use in instruction work led the Signal Corps to request the Bureau to prepare a general textbook of radio communication for the training of radio electricians in the Student Army Training Corps and in the field signal battalions. By the concentrated effort of several members of the staff, ably assisted by a number of specially qualified teachers from various schools, the book was prepared in three months. It has been printed as radio Pamphlet No. 40, of the Signal Corps, with the title, "The Principles Underlying Radio Communication," and has been most favorably received as being simple, intelligible, and nonmathematical, although giving an accurate and fairly complete discussion of the fundamentals of radio work.

SOUND RANGING.

(In normal times the staff of this section is engaged in the study of electrolysis and related problems. During the war nearly all of the staff of the section were assigned to various military problems, especially sound ranging.)

During the year 1917–18 a large amount of time was given to the study of methods of locating hostile batteries by recording electrically the times at which the sound of a discharge reached a number of stations. After comparing the merits of various systems in use, the Bureau undertook to improve the equipment of one type used by the French Army, which appeared most promising. As stated in last year's report, the equipment developed at the Bureau was sent abroad for trial at the front under the direction of two members of the staff who were commissioned for this work, but the plans for this trial were defeated by the death of the senior officer, Capt. Ernest Weibel, from injuries received while on duty at the front.

On the basis of such information as could be obtained from the front and from field tests at the Winthrop Proving Ground, the development of the equipment was pushed actively until the final apparatus was believed to be definitely superior to any other equipment in use. Besides other advantages, the Bureau's equipment was capable of being made up in mobile sets, and thus promised to be especially valuable in the type of warfare which developed during 1918. Sets were sent to France and to Italy, and two more members of the staff had just gone over to put them into operation when hostilities came to a close.

At the request of the War Department, work was continued for some weeks after the armistice was signed, in order to complete the sets then under way, and it is understood that when the reorganization of the Army is completed the cooperation of the Bureau will again be desired in developing a standard type of sound-ranging equipment.

ELECTROCHEMISTRY.

(Electrochemical problems, particularly those involved in the study of electric batteries, electrical properties of chemical compounds, the silver voltameter, and other investigations in electrical measurements.)

Dry Cells.

The circular on dry cells mentioned in the report of last year was completed and published as Circular No. 79. It describes the various sizes and kinds of dry cells, the electrochemical principles involved, and the service which may be expected from dry cells of various sizes. As an appendix to this circular, specifications for dry cells are given which were written at the Bureau and have been formally adopted by the War Department.

A large number of tests have been made for the military departments. The Signal Corps requested an investigation of small batteries for use with radio amplifiers because of the poor service which they had been giving. Six hundred and sixty-four of the batteries of the type Ba–2 were tested at the Bureau, and nearly 2,000 in the military storehouses. In addition, over 400 of the type Ba–5, which is similar in size but arranged for the addition of water at the time the battery is required for use, were submitted for test. The causes of failure of the cells were determined and methods of improving the service were indicated. A larger type of battery for the same purpose was adopted by the Navy Department in accordance with suggestions made by the Bureau, and this type has also been tested in large numbers. Several tests of batteries for use with a trench-signal projector were made for the Bureau of Aircraft Production, and a considerable amount of material for the manufacture of dry cells, intended for shipment to French factories and the overseas plant of the Signal Corps, was analyzed and tested. Samples of batteries intended for use in submarine mines were tested for the Navy Department and an examination was made of dry cells taken from a captured German mine.

The tests of dry cells for the military departments have been special tests in most cases. For the regular commercial testing of dry cells apparatus to control the tests automatically was deemed desirable, since the cells have to be subjected to alternate periods of discharge and recuperation, and for this purpose a control mechanism has been designed and constructed in the Bureau's instrument shop. This apparatus is believed to be superior to any which has previously been used, since one relatively simple piece of apparatus is capable of controlling a number of different tests at the same time, while the equipment which has been in use at various manufacturing plants is generally complicated and can make only a single test. The work of installing this apparatus was begun at the close of the fiscal year.

A large amount of work has been done in studying methods for dry-cell analysis. This involved a comparison of all the available methods for determining the various constituents of dry cells and the selection of those best adapted to battery problems. The methods which were selected have been prepared in the form of a manual that can be put in the hands of a routine worker.

The tests which were made for the military departments showed the need of systematic study of the causes of deterioration of dry cells when not in use and of means for obtaining a satisfactory "shelf life" of cells. This was undertaken during the latter part of the fiscal year. The following lines are considered the most important parts of this research: (1) Measurements of the conductivity of powdered manganese-dioxide ores with reference to the size of the particle and the intercomparison of ores from various sources; (2) the corrosion of zinc by electrolytes containing various concentrations of ammonium chloride and zinc chloride; (3) the potentials of the manganese-dioxide electrode in solutions of varying hydrogen-ion concentrations; (4) the measurement of the hydrogen-ion concentration in various dry cells; (5) the making of limited numbers of dry cells at the Bureau from materials of which the chemical and physical properties have been studied. Much of this research is made necessary by changes in sources of supplies obtainable by the manufacturers which have resulted from the war.

At the request of the Signal Corps, an investigation of the galvanic pile was begun to determine the possibilities of its use where only small currents are required. The Bureau developed a disk cell, containing the ingredients of a dry cell, which compared favorably with the type Ba–5 batteries and avoided the principal source of failure which was found in them. Investigation has also been made of galvanic piles in the form of zinc-copper and zinc-carbon couples.

In connection with the efforts of the Food Administration to conserve foodstuffs the Bureau was asked to render a report on the use of wheat flour in the manufacture of dry cells. It was recommended that the manufacturers be permitted to use wheat flour unfit for human consumption, and this recommendation was acceptable to both parties.

Storage Batteries.

An extended test of storage batteries for the propulsion of electric trucks and tractors was made for the Construction Division of the Army. Measurements of the capacity and efficiency under various conditions were made on batteries submitted by all the principal manufacturers, and the speed and acceleration of an electric tractor when equipped with batteries of the lead-acid and of the iron-alkali types were determined under service conditions. After the report on this test was submitted to the War Department, the Bureau was requested to continue the investigation to obtain additional information needed in the preparation of adequate specifications for tractor batteries. An extended series of measurements was made on the more important types of batteries, and the Bureau assisted in the preparation of preliminary specifications.

A test of the drying of wood separators in batteries shipped and stored without electrolyte was made for the Motor Transport Corps.

A number of extended tests, involving the analysis of acid and alkaline electrolytes for storage batteries, were made for the Signal Corps and the Panama Canal. These tests involved an extended study of the methods available for the analysis of battery acid, particularly with reference to the determination of nitrates and nitrites and other impurities which, if present even in small amounts, have a deleterious effect on the storage battery. The methods of analysis which were found best suited to the battery problems have been prepared in the form of a manual. Considerable research was also necessary for the analysis of the alkaline electrolytes, this being a more unusual problem than that of the acid analysis. The Bureau has collected from manufacturers and large users of storage batteries the specifications for battery acid and finds that the amounts of certain impurities permitted by these specifications vary by 1,000 per cent. As no reliable information is available on the effects of many impurities which are often present in battery acid, a series of experiments to determine these effects was begun and carried on during the year.

Methods for measuring the single potentials of the plates in storage cells have been studied, since this is a valuable method of testing the batteries. It has involved a comparison of a number of different half-cell electrodes and a series of experiments on the cadmium electrode which has been used in a limited way for many years. In this work the errors to which the cadmium electrode is subject were determined, and it was found that by a slight change in the ordinary procedure the more serious of these errors could be eliminated. A series of questions sent to the different manufacturers and a search of the literature on the subject shows that no reliable information as to the use of this electrode and the errors to which it is subject has been available in the past.

The Construction Division of the Army undertook the preparation of a manual on tractor batteries for use in maintenance stations. Fundamental data for this manual were obtained at the Bureau during the tests which had been in progress. At the close of the fiscal year, the Construction Division requested the Bureau to assist in the completion and publication of this manual, and it is to be published by the Bureau as a circular.

The War Department Committee on Education and Special Training also undertook the preparation of a manual consisting of job sheets for the instruction of the enlisted personnel and reserve officers in the operation and repair of storage batteries, and this Bureau was requested to furnish information and to criticize the manuscript.

Railway-Signal Batteries.

During the winter a comparative test of different kinds of railway-signal batteries was made, a number of them being subjected to outdoor weather conditions. It was found that the performance of some makes of these batteries varied greatly with the temperature, and that the usual specifications for test do not make proper allowance for this variation.

RADIOACTIVITY AND X-RAY MEASUREMENTS.

(Methods of measurement of radioactive materials and phenomena, standardization and measurement of radium, mesothorium, radium preparations, and similar materials; study and measurement of self-luminous materials; study and standardization of X-ray apparatus and supplies, and the application of X rays to various investigations.)

Luminous Materials.

Self-luminous materials contain a small percentage of a radioactive material, usually radium, and require no previous exposure to light to excite their luminescence. This property is of great value in many fields, both military and civil. These materials are used for the illumination of airplane dials of all kinds, of bomb sights, compasses of all kinds, gun sights, round counters for machine-gun magazines, targets for indirect fire, dials for navigation instruments, etc. In civil life they are used for the illumination of dials for clocks and watches, for marking push buttons, pull sockets, signs in dark places; in fact, wherever a faint and entirely self-contained illumination is desired.

When the Bureau began the study of these materials in 1916 but little was known and nothing had been published concerning their properties. In particular nothing was known regarding the effective life of the material and but little data was available regarding the brightness that is needed for various purposes. Both are of prime importance in the practical use of these materials. After developing suitable methods for measurement it was to these problems that the Bureau directed its attention.

A considerable amount of data had been obtained by the time the United States declared war with Germany. This was at once placed at the disposal of the Departments of War and Navy, and from that time to the present the study of problems of special interest to these departments has largely supplanted the more orderly investigation of the initial problems. Material bearing upon the latter has, however, been accumulated throughout this time and will be collated with the earlier observations.

During the year cordial cooperation with the various branches of the military departments of the Government has been continued. This has included (1) the furnishing of information concerning the properties of luminous materials and methods for measuring their surface brightness, (2) recommendations regarding specifications and estimates of cost, (3) the measurement of the brightness of selected articles, (4) the preparation and standardization of apparatus and supplies for the factory inspection of dials, (5) the detailed study of selected specimens, (6) the carrying out of miscellaneous experiments, and (7) the preparation of models of articles so designed that the brightness can be varied, by which much useful information regarding the most desirable brightness is obtained.

Among those with whom the Bureau has so cooperated may be mentioned the several divisions of the Bureau of Aircraft Production and of the Ordnance Department, the Engineer Corps, and the Inventions Section, General Staff, Army; the Bureau of Steam Engineering, the New York Navy Yard, and the Bureau of Lighthouses.

Cordial relations with the manufacturers and civilian users of these materials have been maintained. Many requests have been received from the latter for information and advice. These requests have been complied with as fully as possible, but many pertinent and important questions concerning these materials are still unanswered, and can be answered only by the careful work of an authoritative institution, such as this Bureau, that is able to carry on the work over a term of years.

In addition to investigations of various kinds, routine tests of 418 luminous military articles and of 73 civilian articles were made. One mimeographed circular was issued under the title, "Luminous Material Circular No. RLC–6"; it contained information bearing upon specifications for the illumination of articles, and in a slightly modified form will be published by the National Advisory Committee for Aeronautics under the title, "On Self-Luminous Materials."

Standard Radium Solution.

Radium solution of known strength was furnished to the Walter Reed Hospital for medical use.

The public was furnished with 100 cubic centimeters of a dilute solution of certified concentration; such solutions are used for the preparation of standards of radium emanation. These standards are necessary for the determination of the radium content of ores, waters, etc., materials containing only a relatively small amount of radium or of radium emanation.

Radium Emanation Work.

When a material contains but a small amount of radium, its radium content is determined from the rate at which it produces radium emanation. The latter is a radioactive gas produced by the spontaneous disintegration of radium.

Radium determinations by the emanation method have been made for the Walter Reed Hospital and for the Bureau of Aircraft Production.

Gamma-Ray Measurements of Radium.

During the first half of 1918 the rate of receipt of radium for measurement and certification was low. Since July, 1918, it has increased rapidly. Until January most of the material was for export and was intended for military use. Since January the rate of receipt for certification of radium intended for use in surgery and dermatology has far exceeded all past experience of the Bureau.

During the year 474 preparations containing a total of 13,159 milligrams, and of a market value of over $1,500,000, were measured and certified. Of this, 170 specimens, containing a total of 5,065 milligrams, were certified for export, 4,000 milligrams being intended for military use. The preparations for export were distributed as follows:

Country.	Number.	Milligrams of radium.	Country.	Number.	Milligrams of radium.
England	17	2,347.9	Spain	5	67.9
France	92	1,716.3	Australia	6	27.4
Japan	29	673.5	South Africa	1	14.7
Brazil	15	130.6	Argentine Republic	1	11.4
New Zealand	3	70.2	Canada	1	5.3

Since the initiation of its radium work the Bureau has year by year certified radium for export, as shown in the following table, the ratio of the amount certified for export to the total amount measured during the same year being shown in the last column of the table:

Year.	Milligrams of radium.	Fraction of total.	Year.	Milligrams of radium.	Fraction of total.
		Per cent.			*Per cent.*
1914–15	285.5	27.9	1918–19	[a] 1,001.0	[a] 7.6
1915–16	....	....		[b] 4,065.2	[b] 30.9
1916–17	369.7	5.7			
1917–18	357.1	6.7	Total	6,078.5	

[a] Nonmilitary uses. [b] Military uses.

X-Rays.

By costly experience roentgenologists have learned that the protection of themselves from X-rays is of utmost importance. This protection is obtained by the use of lead and of lead-impregnated materials, notably lead glass and lead rubber. When the Bureau began its study of these protective materials it was found that some materials offered for protection were entirely worthless and few of them were as efficient as desired. As stated in the report for last year, the Bureau has been markedly successful in securing an improvement in the quality of these materials.

The study and testing of protective materials has been continued throughout the year, a preliminary determination of the effective absorption of lead glass and of water for radiations of a type widely used by roentgenologists has been made, and the applications of radiography as an aid to various investigations have been studied.

Investigations and tests have been made for the Bureau of Aircraft Production, the Surgeon General's Office, and the Ordnance Department, as well as for other sections of this Bureau.

A paper treating of the early work of the Bureau on protective materials was published in the American Journal of Roentgenology (Vol. V, pp. 472–478; 1918) under the title "Röntgen Ray Protective Materials.." On the invitation of the Western Röntgen Society, a paper treating of the X-ray work and plans of the Bureau was presented before that society at its annual meeting in November.

Roentgenologists are thoroughly awake to the need for the study and testing of all types of X-ray apparatus and materials and are desirous that the Bureau take a commanding position in this work. The many demands made upon the Bureau and the difficulties attending the reorganization of its work on a peace basis have prevented the Bureau from giving to the X-ray work the support that it deserves and requires, but it is hoped that means for remedying this condition may be found in the near future.

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 lines. 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 two years, 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 unprecedented amount of work.

Relation of 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 municipalties will enjoy in large measure the advantages as well as the responsibilities of home rule without its greatest disadvantages.

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 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 or economical 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. The work of the following five sections is largely in connection with public-utility problems:

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.)

Standards for Gas Service.

A large number of cases where standards for gas service were involved have been handled during the past year, some of which are discussed at greater length below. Among these the work for the Indiana Public Service Commission was the most extensive. The investigation requested by the Maryland Public Service Commission at the Annapolis gas works was well under way at the end of the fiscal year, although the final report was not expected to be available for some time. For the North Carolina Public Service Commission the Bureau prepared a suggested supplement to the public-utilities law of that State giving the commission adequate authority, which they apparently do not now have, to adopt standards for service. A survey of gas-plant conditions in North Carolina had been contemplated, but when it was determined that the commission probably did not have authority to fix standards for service the work was postponed. At the request of the chief engineer of the Virginia Corporation Commission, preliminary assistance has been given looking to the adoption of standards for service in that State.

Municipal problems of more or less importance have been covered during the year for city authorities or gas companies in the following localities: Atlanta, Macon, and Savannah, Ga.; Jacksonville, Miami, Tampa, and Key West, Fla.; Columbia and Anderson, S. C.; Durham, N. C.; Atlantic City, N. J.; Houston, Tex.; Sandusky, Ohio; and Louisville, Ky. In all but one of these cases the locality was visited and conferences with one or more interested parties were held.

The work of the Fuel Administration on standards for gas service, especially committee activity looking to the adoption as a war measure of a low national standard for heating value, received considerable attention, and an extensive report on this matter was presented to the Fuel Administration for their consideration.

During the year the third edition of Circular No. 32, "Standards for Gas Service," was by necessity continued in use, but preparation of a fourth edition has been undertaken. This will be completed in the early part of the fiscal year now opening.

Indiana Gas-Standards Investigation.

During the latter part of 1918 the Public Service Commission of Indiana received many complaints regarding the quality of the gas service which was being rendered in a number of cities. Investigation showed that in many cases the poorer quality of gas-making materials available under the existing war-time conditions was responsible for deficiencies in service. A proposed new set of rules for gas service in the State was presented at a public hearing held by the commission in October, 1918, but there appeared to be little information available as to what heating value of gas could be economically produced by the various companies under the existing conditions. The State commission therefore appointed a committee, on which the cities, the gas companies, and the Bureau of Standards, as well as the commission itself, were represented, to recommend to the commission the proper heating-value standard for adoption in the State.

Data and plant records of the various gas companies were collected and carefully examined by this committee. Three very comprehensive tests were run at coal-gas plants in the State, and about 14 other plants were visited in order to determine what heating value of gas they might reasonably be expected to produce. A report containing the recommendations of the committee was finally prepared and unanimously accepted by the committee, and has been presented to the State commission.

In this work the Bureau of Standards has taken an active part. One or more members of its staff were constantly on hand during the progress of the field work, and its senior representative assumed charge of this work at the request of the chairman of the committee.

In the report which has been handed to the commission there are embodied several novel features of gas-standards requirements which, it is believed, will lead to a better and more uniform service to the customers of the various companies. In fact, the Bureau of Standards believes that this investigation which has just closed is the most thorough and convincing effort that has been made in connection with the selection by a public-service commission of a heating-value requirement for a State. Furthermore, the engineering data which have been collected should be of considerable value to the gas industry in the future. The information gained here will be useful in many other cases.

Investigation of Gas Plant at Annapolis, Md.

During the last year or two the local gas company at Annapolis, Md., not only has been unable to operate at a profit, but has not received sufficient income to meet operating expenses. A substantial increase in rates failed to give the necessary financial relief. The Public Service Commission of Maryland, fearing that either another increase in rates or a decrease in the standard of service might ultimately become necessary, requested the cooperation of the Bureau of Standards in determining whether economies or improvements in operation might not be effected which would enable the company to operate more profitably.

A survey of conditions in Annapolis was made and a report submitted to the Maryland Public Service Commission with recommendations as to the management of the gas company. These, if followed out, will ultimately turn a loss into a substantial profit. Possibilities for a considerable extension of business were disclosed, and the Bureau will make detailed recommendations as to the methods it would advise to be pursued in altering and enlarging the plant and other facilities in order to render adequate and satisfactory service.

Gas-Service Inspections.

At the request of the State public service commissions and municipal authorities in many parts of the country, the gas-engineering section of the Bureau has made service inspections or rendered assistance in regard to these subjects. This work has included visits and field investigations in approximately 14 different localities in addition to a large number of other requests which were cared for by correspondence or conference in Washington. This work has enabled the Bureau to place at the disposal of gas companies and municipalities the experience and advice of the Bureau staff on matters that are very frequently the cause of considerable controversy or public agitation. This work has been especially important during the past year and will continue to be so while the high costs of fuel and labor and the difficulty in maintaining the usual high grade of gas service prevail. In many cases the work of the Bureau has shown where conditions might readily be improved to the advantage of all parties concerned. In other cases the Bureau has merely pointed out that the gas company in question was doing all that could be expected of it under the difficult circumstances then existing.

In general the difficulties noted were the result of the extensive disorganization of the gas industry by war conditions and the shortage of fuels of high grade which are best suited to gas making. These conditions, with which the consumer was not always familiar, together with the general increase in gas rates made necessary by high costs, have caused much public dissatisfaction with gas-company operations, and it is natural that outside assistance of this sort from sources clearly not partisan should have been sought. The reports of the Bureau on the conditions found will probably lead to improvement in the relations between the gas companies and the public, as well as, in some cases, to an actual improvement in the quality of service or operating efficiencies of the companies.

Gas-Appliance Laboratory Investigations.

The Bureau is cooperating actively with the industrial fuel committee of the American Gas Association in investigations of gas utilization and burner design. In particular the committee is carrying on a general investigation of the various types of atmospheric burners now in use for industrial purposes.

Up to the present time most of the industrial gas burners have been designed by purely empirical methods, and as a result many of them are far from efficient. The proper design of air shutter, gas orifice and burner throat to give a maximum of air-injecting power under conditions ordinarily met with is the part of the problem assigned to the Bureau. This work is an essential preliminary of the investigations which have been in mind for several years, looking to an improvement in the efficiency of use of gas. The results obtained will serve as a test of the theories which have been developed as to the relation between the physical constants of the burner and the characteristics of the gas used, and should show in a clear and simple way the principles which underlie the efficient utilization of gas in ordinary Bunsen-type burners.

Coking of Illinois Coal.

The great importance during the war period of substituting mid-continent coal for coals from more distant sources, even in by-product coke-oven work, was well recognized. At the request of the War Industries Board, the Bureau of Standards last year made an investigation of a new coke-oven process claimed to be especially suited to this purpose, and in connection with this investigation later conducted a test of a plant in Minnesota, using about 7,600 tons of coal from the Orient mine, Franklin County, Ill. In carrying out these operating tests the Bureau had the cooperation of the Bureau of Mines, and all phases of coal handling, by-product recovery, and laboratory tests were under observation by a staff of 37 Government engineers and chemists employed on the work. In addition, those in charge had the benefit of advice and comment from a considerable number of specialists in the field of coke-oven operation.

All coal used and all by-products obtained were carefully weighed or measured at regular intervals, and samples of each material were taken for analysis. The Bureau of Standards was responsible for the general planning and supervision of the test work. Its representatives made all observations of battery operation, high-temperature measurements, by-product recovery, and chemical-laboratory work on gas and by-products. The Bureau of Mines was responsible for the sampling of the coal, both as it was loaded at the mine and as dumped at the plant. It supervised the weighing, coal-handling, coke-handling, and coke-sampling operations, and made all analyses of coal and coke. Its representatives also made general observations on the character of the coke and operation of the ovens.

In order to test the behavior of the furnace-size coke produced from the Orient coal, arrangements were made to use about 1,800 tons of this material in the blast-furnace plant of the Mississippi Valley Iron Co. Several experts were present during this test, and it was the unanimous opinion of these persons and of the blast-furnace operators that the Illinois coke had shown highly satisfactory results. However, it should be borne in mind that the furnace used for this test was of small capacity, and it is not certain, therefore, that the results in this case would be duplicated in a large-sized furnace.

As a result of the test, it is clearly demonstrated that coke which can be successfully used in a blast furnace can be produced from some of the Illinois coals in the "chamber-type" oven without radical change in the operating methods. However, it appears that the temperature at which Illinois coals should be handled for the production of the best coke is somewhat lower than the best operating temperatures for eastern coals, and, moreover, the speed of coking of the Illinois coals is somewhat less. The yield of gas and by-products from Illinois coal of the kind tested is excellent both in quantity and quality. It should be noted, however, that the coal tested in this case represents one of the best Illinois coals for coking purposes, being lower in ash and sulphur and otherwise superior to many from this field.

Experimental-Retort Tests of Orient Coal.

In connection with other coke-oven investigations it was thought desirable to carry out a short series of experimental-retort tests of Illinois coals to determine the influence of temperature of coking upon the characteristics of the coke and the quantity and quality of gas produced. This work was done at the Sparrows Point plant of the Bethlehem Steel Co., where apparatus was placed at the disposal of the Bureau through the courtesy of the engineers in charge.

The gas produced at high temperatures was much greater in volume but lower in heating value than that produced at the lower temperatures, not only because of more complete elimination of volatile matter from the coal, but also as a result of the greater decomposition of the heavier volatile matter into gaseous constituents at the higher temperature. At the lower temperatures the coke was very inferior to that produced at the higher temperatures, but in no case was the temperature maintained as high as is generally done in coke-oven practice.

Detailed results for the series of five tests are reported in Technologic Paper No. 134. This paper also includes data given to the Bureau by the steel company covering tests made with the same apparatus during the preceding two years.

Proposed National Gas-Safety Code.

The Gas-Safety Code has been advanced very little during this year, but a paper on "Tests of flexible gas tubing" has been prepared and will soon be issued as Technologic Paper No. 133. Unfortunately, there is no prospect of much further progress on the code until additional means are available for the Bureau's gas-engineering work. The Bureau of Standards in carrying out this investigation desires to serve as a national coordinating agency to the end that the resulting code may be adequate for the protection of users of gas, and at the same time acceptable to the casualty and fire-insurance interests, the gas companies and their employees, and the gas-appliance manufacturing and selling interests.

It is well known 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 if the code could be completed and adopted throughout the country, these losses would be considerably reduced, 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 would also serve to unify practice in gas installations and gas-company operation throughout the country, and such uniformity of practice would not only tend to greater safety, but would also contribute to higher efficiency and to more harmonious cooperation between insurance and gas-company officials.

ELECTRIC 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 in 1916 as Circular No. 56, "Standards for Electric Service."

142289—19——6

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 a number of States. The new laws and revised rules have been collected and are ready for inclusion in a new edition of the circular, which will be completed during the latter part of the next fiscal year.

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 in this work when the war necessitated a discontinuance of much of it on the part of the Bureau, and public-utility companies also found themselves unable to cooperate as fully as they would like to do.

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; 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 analyzed, and additional data accumulated.

As in the case of standards for electric service, the Bureau seeks, while representing the public interest, to get the utilities' point of view as well, 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. As in other cases, the information gained will be of great service to the people.

Standards for Heating Service.

At the request of the Public Service Commission of Indiana a study of standards for central station hot-water heating service was begun early in 1918. Field investigations of plants in Ohio, Indiana, and Illinois were made, and conferences were held with their engineers. A proposed set of rules for hot-water 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 steam and hot-water heating service is nearly completed and will be submitted for comment and criticism to the special committee appointed by the National District Heating Association to cooperate with the Bureau, and to other associations and public bodies interested in central-station heating problems. This circular covers the factors affecting adequacy and safety of central-station heating service, the customer's heating requirements, and the various relations with the customer in furnishing such service. It also contains a summary of existing State regulations and of company rules, as well as a set of suggested rules and contracts.

TELEPHONE SERVICE.

(Systems of telephony; standards of telephone service.)

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 in such an investigation. 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 work of the Bureau has been directed along lines which it is believed will best serve all interests concerned. It is seeking to gain, through field and office studies, experimental and theoretical research, and testing, a thorough knowledge of the whole intricate subject of telephony, and through publications, correspondence, and conferences to make its knowledge available impartially to the telephone manufacturing and operating industries, the regulatory commissions, and the telephone-using public.

Detailed studies of the circuits and mechanism of the various automatic or semiautomatic types have been made, and descriptions have been prepared covering the general functions of each switch, the function of each switch element, and the sequence of operation of the elements from the moment the switch is seized in the process of making a call to the time it is released. These studies, together with similar ones of present-day manual systems, supplemented in so far as possible by service observations, will be of value in determining to what extent the different grades of telephone service required under different conditions can be adequately described through standard specifications. Such specifications would be invaluable to public-service commissions in the regulation of telephone utilities with equal justice to the utility and the public it serves.

In order to put into concrete and useful form the information available, the Bureau has in preparation two telephone circulars. The first is intended to give a relatively brief, general description of modern telephone systems and service, and is expected to be published within a few months. The second will describe in considerable detail equipment and service of the type used in cities which have a number of exchanges. In the preparation of this circular the Bureau expects to have the advantage of the continued cooperation of all the telephone interests as well as regulatory commissions, and, as the contents will be submitted to all concerned for criticism and discussion before publication, the circular will not be ready for publication for a considerable time.

Testing of Telephone Circuits and Apparatus.

While the equipment of the telephone laboratory is still far from complete, apparatus is now available for making all reasonable tests for volume and intelligibility of transmission of telephone transmitters, receivers, repeating coils, and of complete talking circuits. The Bureau is also prepared to test transmitters and receivers for their efficiency, as compared with that of standard instruments.

Standardization of Telephone Terms.

During the past half year the standards committee of the American Institute of Electrical Engineers, through its subcommittee on telephony, telegraphy, and radio, representing the various telephone interests and the Bureau of Standards, working in cooperation with the corresponding committee of the British Institution of Electrical Engineers, has been actively engaged in standardizing the definition of technical terms employed in telephony. This work was at first limited to the standardization of terms introduced through the advent of machine switching or automatic telephony, but the scope was early extended to include the whole field of telephony.

To date many definitions have been tentatively agreed upon and have been submitted to the British authorities for their consideration. The large number of terms yet to be defined will receive the active attention of the subcommittee and those cooperating with it when meetings are resumed in the fall.

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 may seriously corrode the pipes and shorten their useful life, sometimes completely destroying 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 litigation 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 considers 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. There are also 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 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 development of leaks caused by electrolysis in order to make the total loss resulting from this cause run well into the millions annually.

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 electroyltic 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 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 Bureau's work was greatly curtailed during the war, since practically all the men formerly engaged in it were diverted to military problems. Since the close of hostilities more active work has again been undertaken, and most of the investigations mentioned below have been carried out during the last few months of the year.

Electrolysis Surveys.

In Milwaukee the question of damage by electrolysis has been in dispute for some time, the city having brought suit against the street railway company to restrain it from further damaging the water mains. Since a controversy in the courts did not promise a satisfactory settlement of this difficult technical problem, the Wisconsin Railroad Commission was asked to exercise its authority in prescribing the responsibility to be assumed by the various utilities in dealing with the problem. The commission, recognizing that the first thing necessary was a more complete knowledge of the facts in the case, requested the Bureau to supervise a survey to be made under the authority of the commission. This survey was made in the fall of 1918 and a report of the findings was submitted to the railroad commission in November.

In Wilmington, Del., the Bureau some years ago suggested that the street railway company use a three-wire power-distribution system to avoid electrolysis troubles. Such a system was designed and installed by the company and proved to be thoroughly satisfactory until very recently, when the rapid growth of the city, with consequent heavy increase in the traffic in certain sections, unbalanced the load on the system, so that there appeared to be a possibility of damage, particularly to important telephone cables which pass through Wilmington. Late in 1918 one of the Bureau's engineers made a detailed study of the situation and assisted in the design and installation of supplementary protection to the cables which it is believed will remedy the undesirable conditions which had developed.

During the last spring two electrolysis surveys were made, one in Marion, Ohio, and the other in Brazil, Ind. The Marion survey was made at the joint request of the utilities and the municipality, and the Brazil survey was made at the request of the Indiana State Public Utilities Commission. Reports have been submitted on both of these surveys which are in the nature of preliminary reports, and as soon as the recommendations embodied in these reports have been complied with it is expected that the Bureau will make some additional tests to determine whether additional remedial measures are called for.

Investigation of Corrosion of Cables in St. Louis.

Shortly before the outbreak of the war, the Union Electric Light & Power Co., of St. Louis, brought to the attention of the Bureau a peculiar case of corrosion of its lead cable sheaths, which appeared, superficially at least, to be very different from that commonly met with in electrolytic corrosion. A few preliminary tests were made in connection with this by the Bureau just prior to the outbreak of the war, but these were dropped when it became necessary to devote all of the energies of the section to the development of war apparatus.

Recently the Bureau again communicated with the Union Electric Light & Power Co. and found that they had not as yet reached any solution of the difficulty and were very anxious to have the Bureau resume the investigation. This was done, and a considerable amount of work has been carried on both in St. Louis and in the laboratories of the Bureau during the past six months. While the investigation is not completed and it is not yet possible to state with certainty the exact cause or causes of the trouble, practically all the evidence thus far obtained tends to show that the trouble is a combination of several causes, chief of which is the fact that during the first few months after the installation of these cable systems they were subjected to very high positive potentials, probably of sufficient magnitude to cause most of the corrosion that is now being observed. Subsequent failures gradually developed, due partly to the elevated temperature at which the cables were operated, which was augmented by a peculiar type of conduit used. The Bureau is at present engaged in investigating a few special questions that have come up, but it is not anticipated that these investigations will change the general conclusion reached.

Improved Methods for Making Electrolysis Surveys.

With the extension of the work on mitigation of electrolysis it has become more and more evident that the older methods of making electrolysis surveys are decidedly unsatisfactory and sometimes may be misleading. Consequently, attention has recently been given to the development of improved methods of making such surveys. Particular attention has been given to developing methods of measuring the current flowing in pipes and the leakage of current from pipes, instead of following the old procedure of measuring the differences in voltage between the different metal structures concerned in electrolysis. The development of these new methods of measurement has required considerable investigation to determine the practicability of applying various principles in the measuring instruments. While none of these investigations are complete, a number of instruments have been built and have given satisfactory results in laboratory tests. Plans are under way to try out these instruments in measurements under field conditions during the next few months.

Experimental Work on Electrolytic Corrosion of Lead.

One of the serious types of damage resulting from the flow of stray electric currents is the destruction of the lead sheaths of cables, which results in deterioration of the cable insulation, and consequently in short circuits and destruction of the cables. Because of the contradictory character of available evidence as to the conditions under which such corrosion of lead occurs, it has appeared necessary to do a great deal of laboratory work to determine these conditions; for example, tests have been made to determine the variation of corrosion with varying current densities in earth, sand, and water. In accordance with previous results, it has been found that the corrosion per unit of current is greater when the actual current density is small than when the currents flowing are large. Another condition which affects the rate of corrosion is the percentage of moisture present in the earth or sand. In general, corrosion takes place more rapidly when there is more water present.

In many places, as the demands for power vary, certain parts of the pipe systems are alternately positive and negative, so that at times the current flows from, and at other times it flows into, the metal. There have been marked differences of opinion as to the electrolytic effects obtained under such conditions, and a long series of experiments have been carried on to determine what the effects are. In these experiments specimens of lead have been made alternately positive and negative for different fractions of the time. The relative amount of corrosion has been found to decrease very rapidly when the portion of time during which the specimens are positive is decreased. It appears probable that in such cases some of the metal is actually redeposited on the specimen when the current is reversed. This, however, has not yet been definitely proved.

SAFETY ENGINEERING AND SAFETY STANDARDS.

(Study of means of reducing hazard to life and property arising from the use of electricity and from other industrial processes; development and application of safety codes for the prevention of accidents, notably the National Electrical Safety Code.)

National Electrical Safety Code.

The Bureau has been engaged for six 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 national 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 poles and steel towers for supporting overhead conductors and to the sags of the conductors so supported. 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 by members of the staff on the latter subject was published in the Electrical World.

Experiments for determining the pressure of the wind upon overhead wires and the shielding effect of wires upon each other where they are closely grouped have been carried out. Models were set up in the wind tunnel and currents of air of different measured velocities were caused to impinge upon them. Measurements of the pressure under such conditions showed that there is a definite shielding effect when two or more wires lie in the same plane which is nearly parallel to the direction of the wind. Experiments in the open air which have been planned by the Western Union Telegraph Co. will be carried out with the cooperation of this Bureau.

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 its usefulness is becoming recognized and its advantages 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 conduces greatly to the general economy, the necessity for which has been emphasized during this period of national stress.

Industrial Safety Standards.

As a result of the work on the National Electrical Safety Code and the numerous points of contact thus established with State authorities and others interested in safety work the Bureau has been called upon to enlarge the scope of this work and to consider safety requirements in other than the electrical industry.

In 1917 the United States Employees' Compensation Commission undertook a general inspection of the arsenals and navy yards of this country from the safety standpoint. The National Electrical Safety Code was utilized as a standard of reference in this work. In order to improve the conditions found safety engineers were appointed by the War and Navy Departments in each one of the navy yards and arsenals, and the engineers so appointed held several conferences 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 which were drawn up to prevent accidents. A set of standards, including the National Electrical Safety Code, was adopted by the safety engineers as a result of this work, and these standards have been applied by the War and Navy Departments.

The need for carrying out work of this kind in a more comprehensive way and with results which should be more generally applicable soon became evident, and the Bureau, consequently, has undertaken a study of other safety rules and has begun the formulation of a series of national industrial safety codes. These will accomplish for other industries what the National Electrical Safety Code has done for the electrical industries. They will be available for the use of State commissions, municipal inspection departments, casualty insurance companies, and others concerned with the application of such rules. The work will be carried out with the cooperation of State and municipal authorities, manufacturers, insurance organizations, technical societies, and other bodies concerned with such matters.

In order to arrange for more complete cooperation in this work and to insure the coordination of the efforts of all parties concerned, a conference was held at the Bureau on January 15, 1919, which was attended by more than 100 representatives of different organizations concerned with safety standards. This conference agreed that the Bureau of Standards was the most suitable agency to take the leadership in this work. It is expected to hold a second conference in a few months to consider further the best means of securing cooperation and of proceeding with the work.

In the meantime the Bureau staff has prepared tentative drafts of rules covering the requirements to prevent accidents, as follows:

National Elevator-Safety Code; National Code for Safeguarding Machines and Machine Drives; National Code for the Protection of Head and Eyes of Industrial Workers; National Code for Safeguarding Remote Control Apparatus. Other industries will be considered as rapidly as the work can be taken up, but the present staff of the section is not sufficient for making very rapid progress.

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 automotive power plants, fuels, and lubricants.]

Thermometer, Pyrometer, and Heat Tests.

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

The number of mercurial thermometers of all kinds, exclusive of clinical theremometers, submitted for test was 4,832, of which 4,100 received certificates or reports. Among those submitted were 479 Parr calorimetric thermometers, 23 high-precision calorimetric thermometers, 121 Beckmann thermometers, 30 clincal standards, and the remainder laboratory and special thermometers of various types, ranging from below 0° C. and up to 500° C. Ninety-nine airplane thermometers of various types were tested for the War and Navy Departments. Of the 19,773 clinical thermometers submitted, 18,503, or 94.1 per cent, were certified. In addition to the above there were tested 11 platinum resistance theremometers and 6 special thermocouples, while freezing-point determinations were made on 75 samples of materials.

In the high-temperature laboratories the following tests were made: Ninety-four thermocouples, 13 indicating instruments for thermocouples, 5 homogeneity tests of thermocouples, 8 optical pyrometers, 9 pyrometer lamps, 2 absorption glasses, 70 melting points, and 7 special tests.

One hundred and sixty samples of metals with certified melting points were distributed.

The heat-measurements laboratory distributed 204 standard combustion samples. Three gas calorimeters were tested. The heating values of a number of samples of gasoline and fuel oil and the thermal conductivities of a number of insulating materials were determined.

A considerable amount of testing done by the section on automotive power plants, fuels, and lubricants, being of an investigative character, is summarized under the work of that section.

The work of testing done in this division was about equally divided between work done for the Government and that done for the public.

Publications.

The following papers relating to the work of the division have been published during the year or are in press. These papers are briefly referred to in various sections of this report:

Misleading Certificates for Clinical Thermometers: Jour. Am. Med. Assoc., February 8, 1919; Am. Druggist and Phar. Rec., February, 1919; The Military Surgeon, vol. 44, p. 297, 1919.

Tolerances for Laboratory Thermometers: Published as a preliminary circular letter.

Thermometers for Airplane Engines: Fourth Ann. Rept. of the Natl. Advisory Com. for Aeronautics.

A Standardized Method for the Determination of Solidification Points, Especially of Naphthalene and Paraffin: Bureau of Standards Scientific Paper No. 340.

The Standardization of the Sulphur Boiling Point: Jour. Am. Chem. Soc., vol. 41, p. 745, 1919; Bureau of Standards Scientific Paper No. 339.

Resonance and Ionization Potentials for Electrons in Metallic Vapors: Phil. Mag., vol. 36, p. 64, 1918.

Electronic Frequency and Atomic Number: Phys. Rev., vol. 12, p. 115, 1918.

Low Voltage Discharge in Sodium Vapor: Jour. Wash. Acad. Sci., vol. 8, p. 513, 1918.

Some Peculiar Thermoelectric Effects: Jour. Wash. Acad. Sci., vol. 8, p. 545, 1918.

Melting Points of the Chemical Elements and Other Standard Temperatures: Bureau of Standards Circular No. 35.

Ionization and Resonance Potentials for Electrons in Vapors of Magnesium and Thallium: Phil. Mag., vol. 37, p. 33, 1918.

Ionization and Resonance Potentials for Electrons in Vapors of Arsenic, Rubidium, and Cæsium: Phys. Rev., vol. 13, p. 59, 1919.

Efflux of Gas Through Small Orifices: Bureau of Standards Scientific Paper.

Fire Tests of Concrete Columns: Proc. Am. Concrete Inst., vol. 15, 1919.

A Comparison of the Heat Insulating Properties of Some of the Materials Used in Fire-Resistive Construction: Bureau of Standards Technologic Paper No. 130.

Fuel Economy of Automotive Engines: Jour. Soc. Automotive Engs., vol. 4, 1919.

Pyrometry: Liddell's Handbook for Chemical and Metallurgical Engineers.

The following 11 papers are to appear in the Transactions of the American Institute of Mining and Metallurgical Engineers:

Thermoelectric Pyrometry.
Temperature Measurements in Rotary Cement Kilns.
Radiation and Optical Pyrometry.
The Melting Point of Refractories.
High-Temperature Control.
Recording Pyrometry.
Heat Treatment of Glass.
The High-Temperature Scale.
Metals for Pyrometer Standardization.
Characteristics of Glass in the Annealing Range.
High-Temperature Thermometers.

The following 21 papers will be published in the fourth annual report of the National Advisory Committee for Aeronautics:

Spark-Plug Defects and Tests.
Properties and Preparation of Ceramic Insulators for Spark Plugs.
Effect of Pressure and Temperature on the Sparking Voltage.
Heat Energy of Various Ignition Sparks.
Temperature in Spark Plugs Having Brass and Steel Shells.
The Subsidiary Gap as a Means for Improving Ignition.
Characteristics of High-Tension Magnetos.

The work described in the above seven papers relating to ignition systems was done with the active cooperation of the electrical or ceramic division of the Bureau.

Synopsis of Aeronautic Radiator Investigations for 1917–18.
General Analysis of Radiator Problems.
General Discussion of Test Methods for Radiators.
Head Resistance Due to Radiators.
Effects of Altitude on Radiator Performance.
Results of Tests on Radiators for Aircraft Engines.
Some Problems of Radiation.
Effect of Compression Ratio, Pressure, and Temperature on Power.
A Study of Airplane Engine Tests.
Power Characteristics of Fuels for Aircraft Engines.
Description of Altitude Laboratory.

Carbureting Conditions Characteristic of Aircraft Engines.
Metering Characteristics of Carbureters.
Effect of Water Injection on Gas-Engine Performance.

The following papers relating to fuels and lubrication are the work of the division of miscellaneous materials of the Bureau:

Viscosity of Gasoline: Bureau of Standards Technologic Paper No. 125.
Report on "Tag" Closed Flash-Point Tester: Proc. Am. Soc. for Testing Mat., Vol. 19; 1919.

Information Furnished.

Hundreds of 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 measurement, industrial temperature installations, melting points, specific heats, heats of combustion and other thermal constants, calorimetry, heat transfer and thermal conductivity, fire-resistive properties of structural materials, industrial fire hazards, fire prevention, safety of combustibles in storage and shipment, liquid fuels, lubricants, automotive power plants, etc. Many engineers and technical men have visited the laboratories for consultation on special problems. A number of devices were submitted for examination and criticism.

Outside Relations.

The work of this division has served many National, State, and municipal bureaus, engineering and technical societies and committees, testing and research laboratories, and many industries in which the measurement or control of heat and temperature are of fundamental importance.

The thermometer laboratories have cooperated with the Standards Department of the State of Massachusetts in matters relating to the testing of clinical thermometers; with manufacturers and testing laboratories on matters relating to temperature measurement and the testing of thermometers; with the Customs Services on the standardization of tests required in collection of import duties; with the military services, by making investigations relating to airplane thermometers; and with the American Association of Clinical Thermometer Manufacturers.

The high-temperature laboratories have cooperated with the representatives of many industries on matters relating to the measurement or control of high temperatures. Papers have been presented at meetings of the American Physical Society, the Optical Society of America, and the Philosophical Society of Washington. The section is represented on committees of the National Research Council and the Optical Society of America.

The section on heat measurements undertook at the instance of the Bureau of Mines, certain low-temperature investigations closely related to the recovery of helium, an extensive investigation of torpedo-power plants for the Bureau of Ordnance of the Navy, and assisted the Bureau of Aircraft Production in a research on captive balloons. Numerous tests of special appliances were made for the Inventions Section of the General Staff, United States Army.

The section on thermodynamics has been represented on committees of the American Society of Mechanical Engineers and the National Research Council.

The low-temperature laboratories have cooperated in special tests for various military agencies and have supplied liquid air to a number of research laboratories.

Members of the section on fire resistance of materials and fire prevention have participated in committee activities of the National Fire-Protection Association, the American Concrete Institute, and the American Society for Testing Materials. The section was also represented on a committee of the War Department engaged in the standardization of equipment. The investigations on the fire-resistive properties of structural-steel building columns are being conducted in cooperation with the Associated Factory Mutual Fire Insurance Cos., and the National Board of Fire Underwriters.

A large part of the work of the section of automotive power plants has been done under the direction of the National Advisory Committee for Aeronautics and in close cooperation with the following agencies: The Bureau of Aircraft Production, the Division of Military Aeronautics, the Motor Transport Corps, the Inventions Section of the General Staff, the General Engineer Depot, the Engineering Division of McCook Field, the Bureau of Steam Engineering, the Bureau of Mines, the Fuel Administration, and the Society of Automotive Engineers. The section was represented on the Interallied Commission on Specifications for Petroleum Products, and on the Committee for Standardization of Petroleum Specifications.

The Bureau is greatly indebted to many manufacturers of automotive power plants, airplanes, and accessories for supplying materials and test specimens required in the investigations carried out in these laboratories. Particular acknowledgment is due in these respects to the Atlantic Refining Co., the Wright-Martin Aircraft Corp., the manufacturers of spark plugs, magnetos, carbureters, and radiators, and the refiners of lubricating oils.

THERMOMETRY.

(Researches on the standard scale of temperature and thermometric fixed points from the lowest attainable temperatures up to about 500° C.; maintenance of working standards within the above range; methods of standardizing temperature-measuring instruments, such as liquid in glass thermometers, vapor-pressure thermometers, resistance thermometers, thermocouples; the testing and certification of temperature-measuring instruments; methods of measuring temperatures.)

Clinical Thermometers.

The matter of misleading certificates for clinical thermometers, referred to in the last annual report, has continued to demand attention. Many manufacturers and dealers have issued certificates which were so worded as to lead the purchaser to believe that the thermometer accompanying the certificate had been certified by the Bureau of Standards. An official letter calling attention to this practice, accompanied by illustrations showing types of these misleading certificates, was published in several of the leading medical and drug journals of the country.

The Bureau has assisted the Department of Standards of the State of Massachusetts in the preparation of testing regulations relative to the enforcement of recent legislation by that State in reference to the sale of clinical thermometers.

Tolerances for Laboratory Thermometers.

In the certification of laboratory thermometers, as in the case of many other measuring instruments, it has been necessary to define certain limits within which the indications of the instruments must be correct. Thermometers found correct within the required limits receive certificates showing the corrections found at the several test points. If the thermometers are not correct within the tolerances, or are otherwise defective, they are refused certification, although, for the convenience of the owner, a report may be issued giving the corrections resulting from the test and stating the reasons why the thermometer was refused certification. A Bureau certificate thus, in addition to the information furnished in the table of corrections, is an indication that the thermometer is of satisfactory quality. A statement of the proposed tolerances applicable to different types of thermometers was issued during the year to manufacturers and others interested in the subject. The tolerances, based on long experience in testing thermometers, were tentatively adopted July 1, 1919, with a view to their subsequent revision, if necessary. The tolerances and other requirements finally adopted will be included in the next revision of Circular No. 8, on the Testing of Thermometers.

Airplane Thermometers.

The work in connection with the development of thermometers for airplane engines was continued this year.

In addition to routine tests of instruments submitted by the Army and Navy, special tests were made from time to time, including vibration tests, tests to determine the variance between readings taken on rising and falling temperatures, tests for lag of reading, etc.

A class of instruction on the construction and use of aviation instruments was conducted for naval aviators by the Bureau at the request of the Navy Department. A lecture on airplane thermometers was given by a member of the section before this class. These officers also visited the laboratory and were shown the methods employed in testing airplane thermometers.

A circular on airplane thermometers was prepared and distributed to departments of the Government, manufacturers, and other interested parties. This circular was revised and has been submitted to the National Advisory Committee for Aeronautics for publication in their report.

Standardization of the Sulphur Boiling Point.

The necessary precautions to be observed in the use of the sulphur boiling point as a fixed point of the thermometric scale are described in a paper published under the above title.

Standardized Solidification Test.

The work of standardizing a method for the determination of the solidification point of naphthalene, undertaken in cooperation with the laboratories of the Customs Service, was brought to a close during the year. The results of the comparative tests based on this method were received and assembled. The excellent agreement obtained by the various laboratories among themselves and with the Bureau indicated the method as adopted to be very satisfactory.

The method has been applied to the determination of the freezing points of other substances. A Bureau publication describing the method and summarizing the results of the work is now in press.

Thermometer Comparator.

During the year a new electrically heated thermometer comparator, employing stirred molten metal to secure uniformity of temperature, was designed, constructed, and put into use. The thermometers are inserted into thin closed-end steel tubes dipping into the molten metal. The temperature distribution is uniform to within about 0.1° C. over a length of about 35 centimeters, from a point about 10 centimeters below the top of the bath. This comparator has proven very satisfactory for the testing of thermometers in the interval 300 to 550° C., and it is believed that similar comparators will find considerable application in the pointing and testing of thermometers by manufacturers.

HIGH TEMPERATURES.

(Researches on the standard scale of temperature and thermometric fixed points in the interval from 500° C. up to the highest attainable temperatures; maintenance of working standards in the above range; standardization and distribution of standard samples for thermometric fixed points [for example, a series of pure metals of certified melting points]; methods of standardization and the testing and certification of pyrometers, such as thermocouples, resistance pyrometers, pyrometer galvanometers, optical pyrometers [including absorption glasses and color screens], radiation pyrometers, etc.; physical properties of materials at high temperatures, such as emissivity [monochromatic and total], specific heats, melting points [of refractories, metals, fire brick, etc.]; ionization and radiation in gases and vapors, etc.; industrial pyrometry and the measurement of the temperatures in industrial processes; the annealing of glass.)

Investigations in Electronics.

Two general types of inelastic impact between an electron and an atom may 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 respective potential differences through which an electron must fall to acquire sufficient velocity for these two types of collision to occur are known as the resonance and ionization potentials for the particular metal in question. The determination of these constants has been continued. Work of this character is of theoretical interest from the standpoint of pure physics, and of practical interest in that it furnishes further evidence toward an explanation of the phenomena of ionization and related problems which arise in the design of vacuum tubes for wireless telephony and telegraphy, rectifiers, etc.

Five papers have been published this year on the above and related subjects, two appearing in the London Philosophical Magazine, two in the Physical Review, and one in the Journal of the Washington Academy of Sciences. One additional paper is in preparation. The constants for 12 different metals have been determined. The results have been correlated with existing spectroscopic data and have also been used for a determination of the universal constant of action giving $h=6.55\times10^{-27}$ erg seconds. Spectroscopic series in lead and arsenic have been predicted on the basis of the data for these elements.

Melting Points of Chemical Elements and Other Standard Temperatures.

A revison of Circular No. 35 makes the data on standard fixed temperatures fairly complete. The edition has been exhausted, and a new edition is in preparation in which a more complete discussion of the high-temperature scale adopted by this Bureau will be presented.

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General Pyrometry.

A treatise on the general methods of pyrometry applicable to the chemical and metallurgical industries is in process of preparation.

Thermoelectric Pyrometry.

Thermoelectric pyrometry is the most important subject, industrially, in the field of high-temperature measurement and control. An extensive paper on this subject has been prepared as one of the Bureau's scientific publications, in which are treated the fundamental methods employed, necessary precautions which must be observed in the use of the various instruments, and general information of importance in technical practice. The above paper is the most complete treatise on recent developments in industrial thermoelectric pyrometry.

Radiation and Optical Pyrometry.

Above 1,500° C. radiation and optical pyrometers afford practically the only feasible method of temperature measurement, and for many processes below this temperature these instruments have proved of great value in the temperature control of industrial processes. A paper, published in the Transactions of the American Institute of Mining and Metallurgical Engineers, under the above title, describes the various instruments and methods employed, and gives in simple form the theories upon which they are based. Many specific applications are discussed, as, for example, the measurement of the temperature of glowing platinum gauze employed as a catalyzing agent. This latter problem arose in the process of nitrogen fixation in the manufacture of explosives. Various tables of data useful in computing temperature measurements are summarized in convenient form.

Recording Pyrometry.

One of the important features of thermoelectric and radiation pyrometry is that printed records of the temperature of a process over an extended interval of time can be readily secured. Many forms of instrument are now manufactured in this country which produce such records automatically. Thus, an operator may be instructed to heat a furnace at a definite rate, and a printed record is available to show whether or not the instructions have been followed. In a paper under the above title, published in the Transactions of the American Institute of Mining and Metallurgical Engineers, the methods employed in recording pyrometry have been considered from the point of view of their industrial applications.

High-Temperature Control.

Not only is it desirable to obtain a printed record of the temperatures in any particular process, but it is essential to have some means whereby a specified rate of heating or cooling may be readily followed. Various methods are employed for this purpose. In certain large installations the temperature-measuring apparatus is centralized by use of a switchboard system similar to the ordinary telephone switchboard. The control operators measure all the temperatures and instruct the operators of the furnaces by means of pneumatic-tube communication or signal system with colored lights. In certain processes the entire control may be made automatic, even to the regulation of valves in a gas or oil-fired furnace. If the temperature of the furnace is too high, the supply of fuel is decreased automatically. A paper has been prepared for publication in the Transactions of the American Institute of Mining and Metallurgical Engineers, in which are discussed the applications of the various processes employed for manual and automatic temperature control.

Melting Point of Refractories.

A knowledge of the melting points of fire bricks, cements, etc., used in furnace construction is necessary in order that the proper factor of safety for the operation of any furnace may be known. A paper under the above title discusses the methods employed for such determinations and the precautions which must be observed, in order that reliable measurements may be obtained. When it is realized that the failure of a large furnace in certain industrial operations may entail losses amounting to thousands of dollars, it is readily appreciated that a thorough study of the thermal properties of the materials entering into the construction of the furnace is necessary.

Heat Treatment of Glass.

War conditions affecting the production of optical glass demanded a more thorough investigation of the annealing processes. To establish effective and economical methods of operation in annealing, it is necessary to determine the practicable annealing temperature range and to investigate certain physical characteristics of the glass in that range. This was done for many different optical glasses. As a result of these investigations, certain relatively simple tests for determining the practical annealing range and annealing procedure for any given glass have been established. An investigation of the distribution of the stresses, the presence of which in the glass necessitates annealing, is also under way with the purpose in view of determining the practicability of establishing standards for the degree of annealing and of studying the relative efficiency of different annealing procedures. Two papers relating to these subjects have been submitted for publication, and a third is in preparation.

Temperature Measurements in Rotary Portland-Cement Kilns.

In connection with an investigation of certain phases of cement manufacture, the Bureau was called upon to measure the temperatures in the sintering zone, rear end, and stacks of a 125 by 8 foot dry-process, coal-fired rotary kiln. Previous to this work no accurate methods of pyrometric measurements in the sintering zone had been described. Using a disappearing filament type of optical pyrometer, and on stopping the kiln, coal, and air supply for a few moments at a time, a series of temperature-time curves, showing measurements on the lining uncovered by clinker, gave the temperature of the kiln. By means of such data burning temperatures and chemical composition of the clinker may be correlated with the object of improving the quality of the finished product. A paper on this subject has been submitted for publication.

Coke-Oven Investigation.

The work described in the last annual report has been completed. Methods of temperature measurement in the process of coking were successfully applied to two types of ovens. The form of the temperature-time curve during coking is an important factor in the production of high-grade coke. A full report of the experimental work is being prepared.

The High-Temperature Scale.

The temperature scale, unlike many other standards of measurement, can not be fixed in terms of a concrete standard. Thus the scale can not be extended by multiplication or division, as is the case, for example, with the meter, the kilogram, the ohm, etc. From the lowest attainable temperatures to the highest temperatures at which a gas thermometer may be employed the latter instrument is used to establish the absolute scale of temperature. For temperatures above the range of the gas thermometer use is made of certain well-established radiation laws. These methods of reproducing the temperature scale each time it is to be used are too elaborate for practical purposes. A number of fixed and accurately reproducible temperatures, such as the melting points of pure metals and the boiling points of certain pure substances, are, therefore, carefully determined on the standard scale of temperature, as defined above, and these fixed points are subsequently used for reproducing the working-temperature scale. The use of such fixed points is illustrated in the following section on standard temperature samples. A paper has been prepared in which are discussed the most important available data relating to fundamental determinations of important fixed points suitable for a definition of the standard working scale of temperature. Values accepted by this Bureau for the definition of its temperature scale are considered in detail, together with methods of interpolation of the temperature scale between these fixed points and the extension of the scale to the highest temperatures.

Standard Samples for Thermometric Fixed Points.

The Bureau issues samples of various metals the melting or freezing points of which have been determined with high precision on the basis of the temperature scale defined as discussed above. By this means the fundamental temperature scale may be distributed to the industries, arsenals, navy yards, universities, and technical laboratories. The demand for these standard samples has been so great that metals are now procured in ton lots when possible. One ton of lead, one ton of copper, and several hundred pounds of zinc and tin have been secured this year. This material is carefully sampled and accurate measurements of the melting points obtained. One ton makes about 1,000 standard samples. A paper has been prepared describing the various samples issued, the chemical analyses, and the methods employed for determining the melting points.

HEAT MEASUREMENTS.

(Measurement over a wide range of temperatures of thermal properties of materials, such as specific heats, latent heats, pressure-volume-temperature relations for liquids and gases; heats of reaction, particularly heats of combustion of solid, liquid, and gaseous fuels; heat transmission and thermal conductivity; development of calorimetric apparatus and methods; and of methods for temperature control, pressure measurements, measurement of heat transmission, etc.)

Standard Heat Samples for Use in Calorimetry.

These samples of certified heating value are used in the standardization of fuel calorimeters. The materials issued were naphthalene, benzoic acid, and sugar. The stock of benzoic acid was exhausted several years ago, and until recently no satisfactory material to replace it had been obtainable. The stocks of benzoic acid and naphthalene were renewed and standardized during the year.

Properties of Methane.

One of the investigations having a military application which was undertaken by the section was the determination of a number of the thermodynamic properties of methane. The knowledge of these properties was very urgently desired by the Bureau of Mines, which was in charge of the production of helium on a large scale for use as a noninflammable balloon gas as a substitute for hydrogen. This project, which constitutes a brilliant engineering achievement, depended on the recovery of the small helium content of certain natural gases. Systematic surveys had shown helium to exist in such amounts as to render this hitherto rare element available in such enormous aggregate quantities as to make its use for military balloons and dirigibles perfectly feasible, if the recovery could be effected at a tolerable cost.

The design and operation of the machinery to effect this recovery most efficiently required a knowledge of the properties of the chief constituent of the natural gas, namely methane.

The properties of methane which were determined by this section were the following: Latent heat of vaporization, specific heat of saturated liquid, specific heat of gas, specific volume of liquid, specific volume of gas, and vapor pressure.

Inasmuch as the accurate measurement of thermodynamic properties of fluids is extremely difficult at best, and, furthermore, as the temperature range throughout which these properties of methane were of interest was far outside the customary range—namely, from 200° to 300° F. below the freezing point of water—the research was taken up with caution and reserve as to the probability of its yielding definite results early enough to be of use to the helium project.

The urgency of the need for the data, combined with the fact that any progress in this comparatively neglected but important field of research would have an intrinsic industrial value, made the attempt seem advisable.

A method for control of low temperature which could be applied to methods of heat measurement was developed, apparatus designed and constructed, defects discovered and remedied, and technique of manipulation acquired in this range of physical measurement. The outcome has been remarkably fortunate in that not only were reliable figures obtained for most of the important properties of methane, but also valuable progress and experience have been acquired which constitute an opportunity for continuation of similar work on other substances, in order to obtain thermodynamic data of importance in technical and scientific work.

As examples of the numerous details in technique of physical measurements involved in this research, wherein especial developments were established, the following two may be noted briefly:

A Calorimeter Envelope or Containing Vessel for Conserving the Heat of a Calorimetric System at Low Temperatures.

This calorimeter envelope is of copper and is hermetically sealed so as to permit evacuation. It is brought to the desired low temperature and controlled by a stream of air, cooled by expansion, tempered by an electric heater, and led through a complex laborinthine tubular network which effects uniform temperature distribution, thus enabling heat losses to be annulled. This is a novel method for thermal control of a calorimeter envelope.

An Experimental Study of Methods for Measuring Specific Heat of Gases.

This particular branch of calorimetry is of especial difficulty, owing to the relatively low heat capacity of a given volume of gas, and the most promising method is to pass a rapid stream of gas at a constant rate through an apparatus called a flow calorimeter, in which the temperature is measured both before and after the addition of a measured quantity of power electrically supplied, the system being so constructed as to avoid unmeasured losses of heat during the process. Several designs of such apparatus suited to low-temperature work have been evolved, constructed, and studied with favorable results as to the prospective ultimate perfection which will permit specific heats of gases to be measured with facility and with definite accuracy.

Properties of Ammonia.

An extensive series of measurements of the vapor pressure of ammonia was completed during the year. The precision obtained in these measurements was high, values being consistent to 0.01° C. or better, except at the lowest temperatures. It is believed that the results obtained are sufficient to meet the demands of engineering and scientific work for many years to come. The range of temperatures covered is from —75° C. to +70° C., which is beyond the range required in refrigeration engineering. The results are being prepared for publication.

With the completion of this work there are available, for the first time, complete experimental data on the properties of liquid ammonia and its saturated vapor, to replace the meager and unsatisfactory data previously available for the calculation of tables of the properties of ammonia.

High-Pressure Gauges.

A 15-atmosphere mercury manometer and a 100-atmosphere piston gauge, constructed several years ago, have been used in several series of measurements during the year and have been intercompared within the range of pressures of the mercury manometer. The piston gauge in particular has been found to be capable of very precise measurements. While this satisfactory performance depends upon good design and correct manipulation, it is nevertheless true that the satisfactory performance depends upon the accuracy with which piston and cylinder are made and fitted to each other, more than upon any other single factor. This very excellent work was done in the Bureau's instrument shop. A description of the gauges and the methods of calibration and use is being prepared for publication.

Gouy Thermoregulator.

This type of regulator, described by Gouy in 1897, appears to have been very little used, although in many cases great improvement in thermostatic control can be obtained by its use. The essential feature consists in controlling the electric heating current through an oscillating contact instead of the fixed contact usually employed. The device has been extensively used in the laboratory during the year, and a paper calling attention to its usefulness and to some of its characteristics has been prepared.

Captive Balloons.

The section cooperated with the Science and Research Division of the Signal Corps (and later with the Bureau of Aircraft Production) in certain important tests relating to captive balloons.

Special Heat Tests.

Tests were made for the Inventions Section of the General Staff of the Army of a small refrigerating machine under consideration for use in cantonments, also of a number of oil burners designed for use in Army cookstoves. The thermal conductivities of a number of samples of lubricating oil were measured in connection with the lubrication investigation being conducted at the Bureau.

THERMODYNAMICS.

(Consultation and research work in technical physics or the physics of mechanical engineering, in particular, applied hydro, aero, and thermo dynamics.)

Efflux of Gases Through Small Orifices.

An important industrial method of metering natural gas requires an auxiliary determination of the specific gravity of the gas. The usual method of determining the specific gravity is dependent on the time of efflux through small orifices. This method was found to be subject to large errors. An elementary theory of the effects of viscosity and thermal conductivity of the gas upon the time of efflux was developed and applied to the observations and shown to account for most of the observed facts. A paper under the above title, prepared in cooperation with a member of the chemical division, has been approved for publication.

Hydraulics.

A theoretical investigation has been undertaken of the resistance of pipes and Venturi meters to the flow of water and other fluids, concerning which there is need for a more systematic general study and analysis of the available experimental data than has yet been published. In the study of Venturi water meters a probable explanation has been found of a puzzling anomaly observed in the behavior of Venturi air-speed meters, which may lead to the improvement of these instruments.

Dimensional Methods as Applied to Physical Problems.

In all of the work of this section material is continually being collected for a publication on the dimensional methods of attacking problems in technical or engineering physics. This very useful method is fast coming to more extended employment, but there is no textbook or treatise on the subject, although one is needed. It is hoped that this want may be supplied.

Heat Transfers.

Some time has also been devoted to the question of planning for research in heat transfer for the subcommittee on this subject of the American Society of Mechanical Engineers, of which the chief of the section is a member.

LOW TEMPERATURES.

(Production of low temperatures 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.)

Operation of Plant.

The liquid-air plant has been operated once or twice a week. Since the liquid air can be stored for several days, this has made it possible to keep a supply in stock the greater part of the time. It has been used for investigations in the low-temperature laboratory, and supplied to various other laboratories at the Bureau, and also furnished to a number of other institutions in Washington and the vicinity.

The carbon-dioxide, low-temperature system was operated almost daily to provide cooling for thermometer comparators, the investigation of refrigeration constants, the testing of aviation instruments, and other investigations.

The large, high-pressure air compressor was employed not only for the production of liquid air, but also to supply compressed air for the production of low temperatures in the apparatus of the thermal-expansion laboratory, the development of new oil-burning apparatus, and other purposes.

Generators for acetylene, hydrogen, and oxygen were maintained in operation, and these gases were supplied to other laboratories.

Liquefaction of Hydrogen.

During the year a new electrolytic hydrogen generator, two gas holders, each of a capacity of 90 cubic feet, and a four-stage hydrogen compressor were installed. As soon as some additional equipment, such as pumps, purifying trains, etc., are secured, means will be available for the efficient production of liquid hydrogen in considerable quantities.

Air Liquefiers.

Two small air liquefiers were constructed for the Bureau of Mines for use in connection with the work on the helium project.

Methane Investigation.

The investigation of the thermal properties of methane, undertaken on account of its importance in the production of helium for use in balloons, which investigation is described elsewhere in this report, is being carried out in the low-temperature laboratories with the use of the equipment where available.

FIRE RESISTANCE OF MATERIALS AND FIRE PREVENTION.

(Standardization of fire tests; fire tests of structural materials and structures; investigations 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-Resistive Properties of Structural Materials.

The object of the investigations on the fire-resistive 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.

Tests Completed.—The series of fire tests of building columns conducted jointly by the National Board of Fire Underwriters, the Associated Factory Mutual Fire Insurance Cos., and the Bureau of Standards was completed during the year. The whole series consists of 106 tests of columns, 76 of which were made prior to July 1, 1918, and 30 during the half year ending December 31, 1918. During the latter period fire tests were conducted on 8 structural-steel columns protected by hollow clay tile or solid gypsum block, 1 unprotected cast-iron-pipe column, and on 6 timber columns, 4 of which were tested unprotected and 1 each protected by plaster on metal lath and by plaster board. Fire tests, followed by water application, were made on 15 columns, representative in type of section and method of protection of those tested in the main series.

Purpose.—The purpose of this investigation is to ascertain (1) the ultimate resistances against fire of protected and unprotected columns as used in the interior of buildings; (2) their resistance, when in a highly heated condition, against the impact and sudden cooling from hose streams.

While columns form the most important element in the strength of a building, few representative tests have been made to determine their ability to support loads when exposed to fire, and fire experience has only a limited value, due to many unknown variables involved. As a consequence, wide differences in requirements relating to the protection of columns against fire exist between different municipal codes and other published regulations. This investigation was undertaken to obtain information on which proper requirements for the various types of columns and protective coverings can be based.

Scope of Tests.—The fire-test series includes (1) tests of representative types of unprotected structural steel, cast iron, concrete-filled pipe, and timber columns; (2) tests wherein the metal was partly protected by filling the reentrant portions, or interior, of columns with concrete; (3) tests wherein the load-carrying elements of the columns were protected by 2-inch or 4-inch thicknesses of concrete, hollow clay tile, clay brick, gypsum block; as, also, single or double layer of metal lath and plaster; (4) reinforced-concrete columns with 2-inch integral concrete protection.

The covering materials for each class of protection were obtained from the main producing regions of the country, the object being to include samples from the principal types of materials that find general application in building construction. The column coverings were applied by experienced men in accordance with plans and specifications drawn to secure average results obtainable under ordinary commercial conditions. A large number of auxiliary tests of constituent materials were made, including several hundred compression tests on the concrete employed.

Method of Testing.—The test columns in this series were designed for a working load of approximately 100,000 pounds, as calculated according to accepted formulas, the amount varying somewhat for the different sections. This load was maintained constant on the column during the test, the efficiency of the column or its covering being determined by the length of time it withstood the combined load and fire exposure. The latter was produced by placing it in the chamber of a gas-fired furnace whose temperature rise was regulated to conform with a predetermined time-temperature relation. The temperatures of the furnace and of the test column were measured at several points with thermoelectric pyrometers, and the deformation of the column due to the load and the heat was measured on two opposite sides over a 37-inch (94 centimeter) gauge length.

In the fire and water tests the column was loaded and exposed to fire for a predetermined period, at the end of which the furnace doors were opened and a hose stream applied to the heated column, the duration of the application and pressure at the nozzle varying with the length of time the corresponding type of column withstood the regular fire tests.

Summary of Results.—Under the conditions of the fire test the columns sustained their loads for periods varying from 11 to 35 minutes for the unprotected steel, cast iron, and pipe columns to over eight hours for some of the heavier concrete protections and reinforced-concrete columns. This proves that unprotected columns are unsuitable for use in locations where fires are possible, and that adequate protection can be obtained by the use of moderate amounts of covering material, properly selected and applied. Large variations were found in the effectiveness of material within a given class, such as between protections of concrete made with different aggregates and of hollow tile from the different types of clay. The method of application was also a large factor in the result, particularly in the case of the protections applied in the form of units or blocks. Duplicate fire tests made with columns protected by coverings of the same material and design gave fairly consistent results, the maximum variation from the average value being within 10 per cent for the protections cast or poured in place and within 20 per cent for those built up of units or blocks.

No column failed in the fire-and-water test series, the principal effect of the fire-and-water application being to loosen or carry away more or less of the covering material.

The preparation of the test results for publication is now in an advanced stage.

Strength of Metals at High Temperatures.

A brief description of an apparatus built for determining the compressive strength and elastic properties of materials as affected by heat was given in the last report. During the year a number of trial runs have been made to test out various details of the equipment and some initial tests completed on specimens of structural steel in the form of standard rolled shapes. These indicate that under constant load of 10,000 pounds per square inch failure occurs at about 575° C., and the limit of utility from the standpoint of further use as a structural member is reached at 500° C. Increasing the load to 20,000 pounds per square inch depresses both points very nearly 75° C.

The work is being continued and will include tests of cast iron, concrete, and timber.

Pyrometer Lag.

With the types of pyrometers used for determining the temperatures in furnaces, and used in fire tests of building constructions, large errors due to the lag of the pyrometer with rising or falling temperatures are usually incurred. The lag is the difference between actual and indicated temperatures, and varies with the rate of temperature change and the type of mounting employed. In fire tests, the temperature rise of the furnace during the first part of the test is very rapid, duplicating in this respect conditions generally present in building fires. Inasmuch as some materials used in structural members and their protections sustain severe damage when subjected to rapid heating, it is important to be able to determine the actual temperatures present in given tests, and, from the point of standardization, to be able to produce a predetermined fire exposure with a given furnace and pyrometer equipment.

During the year a beginning has been made in developing methods for determining the lag constants of furnace pyrometers. The problem is complicated by the varying character of the heat influences to which they are subjected and the difficulties incident with their duplication in a calibrating furnace.

Fire Tests of Concrete Columns.

In this investigation, 28 full-sized building columns of reinforced concrete have been made, 25 have been subjected to the combined fire-and-load test, and 7 have been tested cold, in compression, in the 10,000,000-pound testing machine.

The work done during the year has been twofold in nature, consisting of the making and testing of full-sized building columns of reinforced concrete from aggregates which had not previously been included and in making and testing columns with protective material other than concrete. It has been found that columns made from the so-called Cow Bay gravel—a mixed gravel containing a large proportion of granite pebbles and gneiss pebbles—and columns made from pure quartz gravel gave somewhat poorer results than columns from Pittsburgh gravel previously tested. In the later column tests the protective concrete spalled so badly early in the fire test that a large part of the protective covering, after breaking up into slabs, fell away from the column, exposing the steel and the load-bearing concrete to the fire. These columns failed, under their working load, before the completion of the four-hour fire test. Columns in which the coarse aggregate was trap rock showed no tendency to spall or to crack seriously in the fire tests and retained more than half their original strength as determined by load tests made while the columns were at maximum temperatures at the end of the four-hour fire test. The results shown by columns in which the coarse aggregate was blast-furnace slag were similar to those with the trap-rock aggregate.

Experiments on Methods of Column Construction and Protection.—Since it has been found that columns from gravels of three different types are much less reliable as to resistance to fire than columns of limestone, trap rock, or blast-furnace slag, an effort has been made to develop practical methods whereby columns from gravels of these types, which are in very extensive use, can be so protected as to resist fire, as well as, or better than, columns from the other aggregates without additional cost in construction. Columns have been cast in gypsum forms which were used to serve the double purpose of doing away with the somewhat excessive cost of steel or wood forms and of remaining in place to serve as protection against fire. Forms of this sort, with a light binder of expanded metal or of poultry netting, have been found to stay in place throughout the four-hour fire test and to afford excellent protection. Gravel-concrete columns so protected came through the four-hour fire test much better than trap rock and slag-concrete columns made in the usual way.

It has been found that columns could be made without the usual steel or wood forms by wrapping metal lath around the spiral reinforcing steel and casting the concrete in that. The results obtained indicate that no great difficulty should be experienced in making columns in this way if concrete of medium consistency is used.

Protective Plasters.—Several columns have been made and tested in which a part of the protective covering has been supplied in the form of plaster from Portland cement and sand. These columns gave better results than gravel-concrete columns from the same aggregate, made in the usual way, but not as good as those made from trap rock and slag in the usual way. The trouble with this form of protection is that the outer coat, or coats, of plaster fall off under fire conditions, leaving the column with insufficient protection.

Considerable work has been done in the study of plasters for the protection of gravel-concrete columns and for other purposes. It has been found that, within certain limits, mixtures of gypsum, hydrated lime, and kieselguhr give workable plasters of superior heat-insulating properties. One column which had been cast in expanded metal over spiral reinforcement was covered with approximately 1 inch of a mixture of these materials. Poultry netting was placed over the second coat and concealed by the third coat. A finish coat of gypsum and hydrated lime was used. In the fire test only the finish coat came off. The total thickness of protective material on this column was approximately 1½ inches, and the effectiveness of the thermal protection was such that the highest temperature measured in the steel was 185° C., as against 410° C. in the steel of columns protected by 2½ inches of material in the form of concrete covered by cement plaster.

Fire Prevention.

The section has cooperated, by conferences and correspondence, with Federal, State, and local agencies in matters relating to safety to life, fire protection, and fire prevention.

These conferences related to such matters as fire hazards in various industrial processes, such as cotton ginning, storage and shipment of fertilizers, storage and shipment of petroleum products, pyroxylin plastics, including motion-picture film, etc.

Complete inspections of the properties and occupancies of the Bureau of War Risk Insurance were made at the request of that bureau, and a report was rendered on the fire hazards involved, with especial reference to the safe storage of documents.

A member of the section has participated in committee work of the National Fire Protection Association, the Fire Marshals' Association, the National Safety Council, and other organizations interested in fire prevention and the reduction of fire waste. Considerable work has been done in cooperation with the first of these associations in matters relating to exits from buildings where large numbers of people are housed.

The section cooperated with a committee of the various branches of the War Department in the preparation of standardized specifications for fire extinguishing and signal apparatus and supplies.

AUTOMOTIVE POWER PLANTS AND THE FUELS AND LUBRICANTS THEREFOR.

(Investigation of the fundamental, scientific, and technical problems related to the design and operation of internal-combustion engines and accessories, and the qualities and characteristics of fuels, lubricants, etc., for use in such engines.)

During the first half of the year the work was limited to the immediate necessities of the military departments of the Government and was confined to specific questions of the performance of particular engines and accessories, fuels, lubricants, etc. While carrying out these tests data were obtained which were known to have important bearing on the more fundamental questions relating to internal-combustion engines and which are generally conceded to be of great importance in the economic development of the automotive industry of the country.

When the signing of the armistice afforded relief from the pressure of hurried tests and tentative analyses, the facilities of the laboratory and the time of the staff were turned toward the fundamental questions and the review of the data obtained earlier as a by-product. The topics described below, therefore, parallel very closely the ones listed under this subject in the previous annual report. The advance to be recorded is the marked progress in correlation of the work and its reduction to a form in which the results are available to the automotive industry.

Ignition.

A comprehensive investigation of spark plugs and ignition appliances, commenced in 1916, has been continued, and the results so far attained have been communicated to manufacturers and users of such apparatus, who have shown most gratifying appreciation. The printed reports will shortly be available to the general public in the fourth annual report of the National Advisory Committee for Aeronautics, under whose auspices most of the investigational work was conducted by this section, with the active cooperation of the electrical and ceramics divisions of the Bureau. These reports, seven in number, are entitled "Spark Plug Defects and Tests," "Properties and Preparation of Ceramic Insulators for Spark Plugs," "Effect of Pressure and Temperature on the Sparking Voltage," "Heat Energy of Various Ignition Sparks," "Temperature in Spark Plugs Having Brass and Steel Shells," "The Subsidiary Gap as a Means for Improving Ignition," "Characteristics of High-Tension Magnetos." Each one of these reports is made up of several small reports dealing with a particular phase of the general investigation.

An investigation of the properties of insulating cables in ignition systems was completed. A comprehensive series of oscillograph photographs of magneto-wave forms was obtained and is available for inspection, but not for reproduction and general distribution.

Radiators.

The experimental work of the past two years, conducted largely under the auspices of the National Advisory Committee for Aeronautics, has been compiled in seven reports, which will shortly be available to the public in the fourth annual report of that committee, under the following titles: "Synopsis of Aeronautic Radiator Investigations for 1917–18"; "General Analysis of Radiator Problems"; "General Discussion of Test Methods for Radiators"; "Head Resistance Due to Radiators"; "Effects of Altitude on Radiator Performance"; "Results of Tests on Radiators for Aircraft Engines"; "Some Problems of Radiation," each of which deals with a number of specific problems in this particular line.

The laboratory measurements have been completed on flat-plate radiators, fin and tube radiators, and whistling radiators. The effect of yaw on head resistance and heat dissipation has been studied. An analysis of the best proportions in radiator design to accomplish specified results is in progress. This will enable manufacturers to apply directly the results of two years of scientific work relating to the most important features of radiator design and construction.

Much experimental work is still in progress to determine more completely such fundamental data as pressure drop of the air through different types of radiator tubes, temperature distributions, measurement of mass flow of air, etc. Theoretical investigations are under way relating to air-cooled engine cylinders and to increased radiator requirements imposed by the use of superchargers on aircraft engines.

Altitude Laboratory.

The Bureau has the only "altitude laboratory" constructed to date in this country. This is a small room with reinforced-concrete walls strong enough to withstand the pressure produced on the outside by exhausting the air within to a pressure as low as one-third atmosphere. The engine under test is mounted on a suitable stand within this chamber. The air supplied the engine at these low pressures is also cooled in order to reproduce as closely as possible atmospheric conditions existing at high altitudes. Aviation engines have been operated in this chamber simulating flight at over 30,000 feet, but under conditions permitting of careful scientific measurements. Comprehensive tests were made of the performance of sample engines in advance of quantity production for the purpose of selecting suitable manifolds, carbureters, etc., with respect to performance under flight conditions. Information obtained in such tests had an important bearing on the selection of the equipment for the Hispano-Suiza, type E, aircraft engine. A careful study was made of the performance, under altitude conditions, of the well-known "Liberty 12" engine. A description of this laboratory and the more general results obtained in it have been collected in a series of four reports which are being published by the National Advisory Committee for Aeronautics in their fourth annual report under the following titles: "Effect of Compression Ratio, Pressure, and Temperature on Power"; "A Study of Airplane-Engine Tests"; "Power Characteristics of Fuels for Aircraft Engines"; and "Description of Altitude Laboratory."

The hastily constructed altitude chamber, housed in a temporary stucco shed, which met the immediate needs of the military work, is being replaced with a better-designed chamber in a permanent brick structure. Provision has been made in this laboratory for equipment which will be available for work of interest to the automotive industry of the country. The constructional work on this building is now nearing completion, but the equipment is not fully installed.

Flame Propagation in a Gas-Engine Cylinder.

A method for the measurement of the rate at which the flame is propagated in an engine cylinder while operating under service conditions has been developed in cooperation with the electrical division of the Bureau and has proved successful. The preliminary results obtained by this method of measurement indicate a speed of propagation less than that commonly assumed by designing engineers, and the final results, when available, will have an important bearing on engine design.

Pressure Cycles Occurring in Gasoline Engines.

Indicators for the measurement of the pressures in heavy, slow-speed engines prove useless on the light, high-speed engines for aircraft, because of inertia of their moving parts. Two new indicators are being developed with much promise of success. The successful development of an indicator suitable for use at high speeds will provide a most useful instrument in the development of high-speed, internal-combustion engines.

Carburetion.

This work is part of an extended program, including the fundamental physical questions concerning vaporization and atomization of fuels in carbureters, engine manifolds, and cylinders; apparatus has been designed, constructed, and used for the purpose of studying the metering characteristics of both airplane and automobile carbureters as affected by barometric pressure, rates of air flow, air temperature, engine speed, etc. With a view to the determination of the fundamental principles of operation, an investigation has been made of the relative performance of various methods for the automatic and inherent compensation for changes in metering characteristics with change in barometric pressure; that is, altitude.

Two papers collecting results of this experimental work have been completed and transmitted to the National Advisory Committee for Aeronautics for publication in their fourth annual report under the titles, "Carbureting Conditions Characteristic of Aircraft Engines"; "Metering Characteristics of Carbureters."

Effect of Water Injection on Gas-Engine Performance.

An extensive although still incomplete series of experiments on this subject has been made. The results so far obtained show no appreciable gain in power or energy with water injection. The report of these experiments has been communicated to the National Advisory Committee for Aeronautics, which will publish it in their fourth annual report.

Tests of Special Engines and Accessories.

Numerous special tests were conducted during the year, including one on a small, direct-injection, Marburg, heavy fuel engine, a "barrel" type engine, and a special 16-valve-head Ford engine, and two battery-charging sets, tested for the Signal Corps for reliability.

A specially designed mercury-cooled exhaust valve has been found very successful in a Hispano-Suiza aircraft engine and will help to solve a problem of special importance in an engine of this type.

Petroleum Conservation.

From the beginning of the war the work of the Bureau of Mines on automotive-fuel conservation was actively supported by the Bureau of Standards through close and constant cooperation. At the meeting of the Interallied Commission on Specifications for Petroleum Products of the Interallied Petroleum Conference some of the delegates from our Allies urged a very rigid gasoline specification for fuels for use in combat aircraft, basing their recommendations on their own satisfactory experience with certain gasolines, but without full knowledge of the possible performance of other gasolines. The adoption of such close specifications would have materially reduced the available supply of combat aviation gasoline and introduced unnecessary expense and serious difficulty, not only in production but in overseas shipment and distribution. A careful comparison of the power-producing qualities of 10 different gasolines selected through cooperation with the Bureau of Mines was made by actual engine tests under flight conditions in the altitude laboratory of the Bureau. A report on these tests was the only quantitative data presented to the Interallied Commission on this subject, and it resulted in the adoption of more liberal gasoline specifications, which were amply justified in service and which resulted in a saving to the American people of millions of gallons of oil in their fields and thousands of dollars waste effort in the refining and distribution in France of aviation gasoline.

Fuel Comparisons, Fuel Savers, and Kerosene-Burning Devices.

In addition to service tests on common and aviation gasolines a number of synthetic fuels were tested at the request of the Bureau of Mines and the Navy Department, respectively. Reports were prepared on the performance of "Hector" fuel, a mixture of 70 per cent cyclohexane and 30 per cent benzol developed by the Bureau of Mines, and "Alcogas," a fuel containing a large percentage of alcohol. The general conclusions from these tests will be compiled for publication. Five proprietary preparations intended to be used as gasoline substitutes were tested for the military service. Many of the so-called "gasoline improvers" were tested for the Inventions Section of the General Staff of the Army. Two devices for the convenient use of kerosene instead of gasoline in the usual gasoline engine have also been tested for this section.

Lubrication.

The work on the general subject of lubrication has been carried on under the supervision of an oil committee representative of the Automotive Power Plants Section, the miscellaneous materials section, and the Chemistry Division.

Lubrication of Internal-Combustion Engines.

Prompted by the desire of overcoming lubrication difficulties experienced in airplane engines, the Bureau of Aircraft Production initiated at the Bureau of Standards a thoroughgoing investigation of lubricating problems. A complete program was drawn up to cover the entire complex situation to be investigated and a new laboratory was equipped for the purpose. The work done in this laboratory up to the end of the fiscal year has been confined largely to apparatus design. Some of the investigations planned have been begun, but no completed results can be reported.

The following apparatus necessary partly for routine tests and partly for new investigations has been completed and is now in use: Oxidation oven for commercializing the Waters' oxidation test; Herschel emulsifier for making demulsibility tests; apparatus for measuring gasoline absorption; battery of Saybolt viscosimeters provided with electric heating and thermostatic temperature control; vacuum-distillation apparatus for lubricating oils.

Standardization of Instruments.

In continuation of the work of viscosimeter comparisons, the Ubbelohde viscosimeter has been investigated and the viscosity of various samples of gasoline determined. This work is described in Technologic Paper No. 125. The Redwood viscosimeter is now under investigation.

The Bureau's report on the "Tag" closed flash-point tester was published by the American Society for Testing Materials, as an appendix to the report of the committee on preservative coatings for structural materials, and was presented at the annual meeting of the society, June 24–27, 1919.

Friction Machine.

Considerable work has been done to determine the relation between viscosity and friction and the conditions necessary to obtain reliable results with friction machines. This work is being continued. A new friction machine for the particular purpose of studying the lubrication problems arising in connection with internal-combustion engines has been completely designed and is in process of construction.

Routine Physical and Chemical Tests.

The ordinary physical and chemical tests of lubricating oils, consisting chiefly of the determination of the viscosity, flash point, fire point, pour point, demulsibility, acidity, percentage of fat, and percentage of ash, have been made according to generally accepted methods on many samples submitted by Government departments. Oils for internal-combustion engines and for other special uses were also tested by Conradson's method for carbon residue, as well as by the Waters' method for the carbonization value. The latter method was developed at the Bureau.

During the year physical tests were made of 529 samples of lubricants and chemical tests of 557 samples.

4. LIGHT AND OPTICAL INSTRUMENTS.

[Spectral analyses; measurements of standard wave lengths; aerial photography; standards and testing of sugar and other materials by optical means; general polarimetry; color measurement and specification of color standards; spectral transmission and reflection of dyes and other materials; design and testing of optical instruments; testing of optical glass; radiometry; investigation of dispersoids; interferometry.]

SPECTROSCOPY.

(Spectroscopic investigations of metals, rare earths, and rare gases; red and infra-red investigations of the atmospheres of the sun and the earth; development of infra-red photography for aerial observations.)

Red and Infra-Red Spectra of Chemical Elements.

The principal work of the spectroscopic laboratory is the determination of standards of wave length in the spectra of the chemical elements. Because of its experience in the use of photographic plates sensitized to red and infra-red light, it has devoted considerable attention to the investigation of these long wave regions of the spectra of the chemical elements. Although the greater portion of the time and energy was devoted to war problems described below, yet considerable progress was made in spectroscopic research. The investigations of the red and infra-red spectra of silicon, titanium, vanadium, chromium, manganese, molybdenum, tungsten, and uranium reported last year as being in progress are now completed, and the data have been collected for publication. Similar studies of the rare gases krypton and exnon have been completed and are now in press. The investigations of zinc, cadmium, mercury, aluminum, tin, lead, antimony, bismuth, silver, and gold are nearing completion, and investigations of the rare-earth elements yttrium, lanthanum, cerium, samarium, thorium, erbium, etc., have been started.

Applications to Astrophysics.

The study of the red and infra-red spectum of the sun mentioned in the last annual report has been completed. Additional spectrograms on plates bathed with pinacyanol and dicyanin have been secured with the Porter spectrograph of the Allegheny Observatory. These plates have been measured and reduced and the results are now in process of publication. Briefly, it has been found that in the portion of the sun's spectrum comprised between the limits 6,500A and 9,000A there are more than 2,400 Fraunhofer lines. Of these nearly 60 per cent are produced by the earth's atmosphere, the remainder being of solar origin. Over 500 of the 900 lines due to absorption in the sun's atmosphere indicate the presence of 27 chemical elements whose spectra have been investigated in the red and infrared regions.

Spectroscopic Analyses.

Spectroscopic analysis affords a rapid and accurate method of examining minerals, ores, metals, alloys, and various compounds for which a qualitative analysis is desired. In some cases it is also possible to make quantitative analyses as well. During the year the following substances have been analyzed spectroscopically: Five samples of tungstic oxide, smokeless gunpowder of German and American manufacture, five samples of ores containing zirconium, six samples of barium chloride, two samples of gallium, two of tin, and one of very pure magnesium wire. In addition to the above substances, whose arc or spark spectra were photographed for purposes of analysis, low-pressure tubes containing samples of "C" gas used in filling dirigible airships were made and their spectra examined. This gas was found to be chiefly helium contaminated with air.

False Spectra Produced by Gratings.

In the course of the investigations on the infra-red spectra of various metals it was noted that many lines of apparent wave length greater than 10,000A corresponded to lines of shorter wave length in the visible red region of the spectrum. The ratios of the wave lengths of the visible red lines to the corresponding lines in the infra-red region were found to be constant and to be of four values; that is, each line produces at least four false lines or "ghosts" at remote distances from the exciting lines. The existence of "ghosts" near the exciting lines and of the remote ones discovered by Lyman in the ultra-violet has been known for some years. These discovered in the infra-red may be of the Lyman type, but if so are due to a ruling error different from that in the grating used by Lyman. Their presence has made it desirable to study the imperfections of diffraction gratings, and accordingly the Bureau has borrowed a number of gratings ruled at the Johns Hopkins University for the purpose of studying the nature and causes of the false spectra given by them.

Low-Pressure Tubes for Spectroscopy.

The spectra of gases are studied by passing an electric discharge through a tube containing the gases at low pressure. Frequent requests come to the Bureau to supply tubes for use in astronomical and physical investigations. During the year 38 tubes have been filled with oxygen, hydrogen, helium, neon, and mercury. Attention is called to the fact that the helium used for this purpose was obtained from the gas wells in the western part of this country, from which helium is taken for use in dirigibles. The helium as used in the dirigibles is contaminated with impurities which are removed when a tube is prepared for spectroscopic work.

Spectroscopic and Optical Apparatus.

The spectroscopic laboratory has during the year produced some apparatus of various types to meet its own needs and the needs of others who have come to it for assistance. To facilitate the securing of spectrograms a new arc stand was designed and constructed and also a new plate holder.

For qualitative work in the study of low-pressure tubes, flames, arcs, etc., a new direct-vision spectroscope has been designed, using glasses made by the Bureau of Standards. Also a large number of replica gratings have been made for the same purpose. These have been supplied to various Government laboratories, which have found them useful in qualitative work.

A photographic lens corrected for red light has also been computed. This lens is in process of construction at present in the optical shops of the Bureau.

Aerial Photography.

It is well known that the ordinary photographic plate when exposed in a camera does not reproduce exactly what the eye sees.

This is because the ordinary plate is affected by only blue and violet light, for which the eye is relatively insensitive, and is scarcely at all affected by the green and yellow, for which the eye has its maximum sensitivity. These ordinary photographic plates are practically insensitive to red light and are therefore handled with safety in light from a ruby lamp. It has long been known, however, that photographic plates may be made sensitive to green, yellow, and red light by the admixture of suitable dyes to the emulsions on the plates.

A plate sensitive to these longer waves possesses some marked advantages over the blue and violet sensitive plate. A panchromatic plate reproduces more faithfully what the eye sees, and when exposed behind a ray filter or color screen it portrays objects which, on account of haze, smoke, etc., would be hidden from an ordinary plate and also gives different contrasts, depending on the nature of the light transmitted to the plate through the filter. The phenomenon of haze penetration by the longer waves is known to most outdoor photographers. Not only haze due to water vapor, but smoke haze, which looks bluish to the eye, is largely eliminated by using light of longer wave length than that which is most effective in case an ordinary unscreened plate is used. Objects completely obscured on an ordinary unscreened plate by haze or smoke may be shown in good detail by using a panchromatic plate and a red filter. Such red sensitive plates, of course, can not be handled in the presence of the well-known dark-room ruby lamp, but must be developed in complete darkness or in a very weak green light. To obtain the long-wave advantages of haze penetration and contrast mentioned above the photographic plates must have the greatest possible sensitiveness to yellow, orange, and red light if the exposure times are necessarily short on account of rapidly moving objects or if the camera itself is in rapid motion, as is the case in aerial photography. When corrected camera lenses giving very bright images are not to be had it is even more necessary that the photographic plates be of the highest possible sensitiveness.

During the war aerial observation early came to play a prominent part, and it became a matter of great importance to have a suitable panchromatic plate for aerial photography. Laboratories and research organizations in various allied countries were busily engaged in trying to produce plates of extreme sensitiveness or speed. The best commercial orthochromatic (sensitive to blue, green, and yellow) and panchromatic (sensitive to all colors) plates were too slow for most purposes. For many years, however, physicists had used yellow and red-sensitive plates which greatly exceeded in speed any of the commercial plates. These plates are prepared by bathing an ordinary photographic plate (sensitive to violet and blue) in certain solutions of aniline dyes, and at the expense of keeping qualities such plates may be made much more sensitive to red light than any plate known to commerce. After several years of experience with such plates in spectroscopic investigations by the Bureau of Standards, it seemed worth while, when the United States declared war upon Germany, to make an application of them to landscape photography. Accordingly, experiments were made in 1917 to determine the practicability of using the bathed plates for landscape photography, with the hope that either this method might be a useful addition to the photographic methods of our military forces or that the experiments would lead to improved commercial plates which incorporate sensitizing dyes in the photographic emulsions.

Preliminary tests with apparatus that was inadequate to test the real merit of the bathed plate proved encouraging enough to warrant a continuation of the investigation with better apparatus (more suitable cameras and ray filters), and with new dyes of British manufacture.

The attention of the Science and Research Division of the Signal Corps was attracted to these early results and the Bureau of Standards was given the opportunity of comparing the stained plates with various plates used by the military forces. Among these were several types of British-made panchromatic plates then in use on the western front for aerial photography. A series of experiments soon showed that pinacyanol stained plates were at least four times as fast as the best commercial panchromatic plates then in use. In particular, plates stained with some new dyes of British manufacture were found to be much superior to any commercial panchromatic plates not only in speed, but also in the range of color sensitiveness.

These encouraging results led to the offer of the Bureau of Standards to supplement the photographic work of our military Air Service by adding to it a new method which would probably be of great military importance in special photographic work, such as the penetration of haze and smoke, detection of camouflage, etc., where the ordinary commercial plates could not be satisfactorily used. The assurance of cooperation from the War Department was received and the Bureau invited by the Signal Corps to test the bathed plates in aerial photography as soon as facilities permitted. Extensive experiments were made at Langley Field during the spring and summer of 1918 under the generous auspices of the Science and Research Division of the Signal Corps, and after the armistice was signed the flying facilities of Bolling Field were used to a limited extent to complete the experiments.

Early in 1918 a representative of the spectroscopic section of the Bureau of Standards who was in France was requested by the French military authorities to assist the French photographic section in making fast-color sensitive plates. A temporary laboratory was installed similar to the ones at the Bureau of Standards, with the exception that the plate-drying cabinet was arranged so as to use air heated by a gasoline stove. This was necessary on account of the low temperature and high humidity prevailing in northern France in winter. The following experiments with bathed plates were made there: Ordinary fast plates were stained with pinaverdol and pinacyanol with ammonia; orthochromatic plates were bathed in pinacyanol with ammonia; panchromatic plates were bathed in ammonia. Each type of plate was used in three ways—unscreened, with a deep yellow screen, and with a red screen. The bathed plates were found to be somewhat faster unscreened than any plate actually used by the French. Using screens, the bathed plates were shown to be much faster, particularly for red photography. This matter was also considered of very great importance by the American Aviation Section, and it was requested that one of our physicists cooperate with them on experiments of this kind. This cooperation was offered, but was not strongly supported by the military authorities in this country, largely on account of the fixed idea that bathed plates had only reached the experimental stage. Considering the special equipment and technique required by such plates, their use at the battle front was held in abeyance, with the hope that commercial panchromatic plates of sufficient speed would be forthcoming.

The success with which dye-sensitized photographic plates had been used in the laboratories of the Bureau convinced this section of the possibility of their being of extreme importance in special military applications and impelled the Bureau to demonstrate their value by careful measurements in the laboratory and tests in the field. In addition to the problems of ordinary photography the use of bathed plates with light filters involved, (1) a study of photosensitizing dyes and of the spectral sensitivity which they imparted to ordinary photographic plates, (2) experiments still further to increase the speed of color-sensitive plates, (3) investigations of the spectral distribution of energy reflected from landscape, etc., (4) design and construction of new photographic lenses for use with red light, and other similar problems. A detailed report of this work was made under the title of "Photographic researches."

Hypersensitizing Commercial Panchromatic Plates.

The speed and color sensitiveness of photographic plates are of extreme importance in military photography to obtain results under unfavorable conditions of light intensity, haze, relatively low-speed cameras, etc. It is, therefore, obvious that a commercial panchromatic plate with good keeping qualities is, if sufficiently fast, more economical than a stained plate. The cause of the superior speed of the stained plate, perhaps, lies in the use of ammonia in the staining bath. It became, therefore, a matter of interest to see to what extent commercial panchromatic plates could be hypersensitized by treatment with ammonia. Experiments showed that ammonia increased the speed of various brands of panchromatic plates from two to four times and also extended the sensitiveness to considerably longer waves. The treatment consists in soaking the plate prior to using, for four minutes in a bath containing 75 cubic centimeters water, 25 cubic centimeters ethyl alcohol, and 3 to 4 cubic centimeters of strong ammonia. Plates so treated have been used successfully in aerial photography, and also for spectroscopic work in various scientific laboratories and astronomical observatories.

Dyes for Photographic Sensitizing.

Ordinary photographic plates, which owe their sensitiveness to the silver halides alone, are sensitive only to the blue, violet, and ultra-violet regions of the spectrum. If, however, a suitable dyestuff be added, the emulsion becomes sensitive to other regions, the particular region depending on the dye used. The dyestuff is applied to the halides in one of two ways: In the commercial orthochromatic and panchromatic plates the dyes are incorporated in the emulsion and the mixture is flowed over the glass plate. The second method consists of bathing an ordinary blue-sensitive plate in a dilute solution of the dye and allowing the plate to dry. The dyes most valuable for sensitizing photographic plates to the longer wave portions of the spectrum are commonly known as pinaverdol, pinacyanol, and dicyanin. Pinaverdol sensitizes a blue and violet sensitive plate to the green part of the spectrum; pinacyanol sensitizes from green to red; and dicyanin is most efficient in photography of the red and infra-red spectrum.

Previous to the war practically all of the dyes which were most successfully used in photographic sensitizing were produced in the large dye factories in Germany. When this source of supply was cut off, not only was the commercial color-sensitive plate manufacturer put to some trouble to find substitutes for the dyes he formerly imported, but the physicist also, who prepared bathed plates for special problems, seemed likely to have to discontinue his work because of the shortage of dyestuffs.

Photographic Dye.—The spectroscopy section of the Bureau of Standards had been making extensive use of photographic dyes in spectroscopic work during the past five years, and attention was called at the beginning of the European war to the importance of making such dyes in America. Upon the entrance of our country in the war the urgency of work on photosensitizing dyes was insisted upon, and this work was earnestly undertaken by the chemical division of the Bureau of Standards and by the Bureau of Chemistry of the Department of Agriculture. The spectroscopy section of the Bureau of Standards maintained close relations with this work and cooperated by testing the photosensitizing properties of all the samples of dyes submitted for this purpose. During the past year nearly 100 different samples of such dyes were tested, and many of them were found equal or superior to their foreign predecessors in usefulness for photography. Quite aside from the importance of such excellent photosensitizing dyes for use in military photography their value in spectroscopic and astronomical researches of the future can not be overestimated.

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.)

The Rare Sugars.

There are now known and are being used by the Medical Service of the War Department and the general public about 20 of the so-called rare sugars. The demand for a highly purified dextrose (glucose) has become so great that its production has increased to a point where it can no longer be designated as a rare sugar, but must be placed in the same category with ordinary sugar (sucrose).

Unfortunately, there is in existence but little scientific data on the rare sugars, and practically all there is is inaccurate and wholly inadequate for modern usage. Many of these sugars undoubtedly have valuable properties unknown at this time. One of their principal uses is the differentiation of bacteria, for which purpose they are invaluable.

During the year the Bureau has had presented for test a number of these rare sugars. Necessarily, their investigation requires careful research, so that progress is slow. The demands on the Bureau for this work are so insistent and continuous that plans have been drawn for a section wholly devoted to the scientific exploration of this important field. The sugars are nearly all expensive to produce; their current values ranging from a few dollars to $350 a pound. A number of them might have great commercial importance if they could be produced at a reasonable cost. The results which the Bureau has attained in this work during the past few months are most encouraging.

Production of d-Mannite.

At the request of the War Department, the Bureau has undertaken the production of a considerable quantity of d-Mannite. This little-known sugar is utilized on an extensive scale by the Army Medical Service. The source of supply is a crude manna. The Bureau's investigation finally developed a method whereby pure white crystals of d-Mannite can be produced by two crystallizations from the crude manna. It thus became possible to produce relatively large quantities of the valuable substance at a reasonable cost. The Bureau is now engaged in this work and will produce 1,000 pounds of the pure material.

A New Fixed Point on the High-Temperature Scale.

The successful termination of a scientific research, no matter what its character, almost invariably leads to an extension of knowledge in other directions than those contemplated within the scope of the original problem.

The investigation of the natural rotation of light by crystalline quartz at high temperatures has developed new and unexpected phenomena. Additional knowledge of the properties of quartz is of importance from the theoretical standpoint because of its extensive use in polarimeters and other instruments, and because of its relation to problems involved in the study of the history and the formation of the earth.

At a temperature of about 573° C. crystalline quartz changes into another crystal, with a transformation of energy during the process. The discovery made by the Bureau is that the temperature at which the transformation starts when the crystal is being heated is a very definite and sharply defined one. A careful investigation has shown this point to be 573°.3 C. The transformation of energy at this temperature is apparently far sharper and more easily determined than that utilized in determining the ordinary points on the high-temperature scale. It is found that a thermocouple close to but not actually in contact with a small plate of quartz will record this point with high precision. To obtain the best results the thermocouple should be inserted in a small opening in the crystal, thereby standardizing it at a fixed and accurately known temperature. A study of quartz from various geograpically widely distributed sources shows that the phenomenon is common to all crystalline quartz. Also the temperature of 573°.3 C. is a fortunate one in that there is now in existence no known method of conveniently calibrating temperature-measuring devices in this region. Not the least important advantage is the ease with which a thermocouple can be standardized by the use of this method.

Natural Rotation of Quartz at High Temperature.

The investigation of the natural rotation of light by crystalline quartz at high temperatures has been continued. As the temperature of a crystal of quartz approaches 573° C. there occurs a most profound change in all the physical properties of the crystal. It has been found that there is an especially abrupt change in the optical properties. When light, vibrating in a single plane, is passed through the crystal, the rotation of the plane of vibration which ordinarily occurs in crystalline quartz is found to suffer an abrupt change as the temperature of 573° is approached, the magnitude of the change depending on the wave length or color of the light used. When a curve is plotted, showing the variation of the rotation with the temperature, it is found that above 573°.3 C. there is comparatively little change in the rotation for relatively large changes in temperature. The Bureau's recent work has found that the curve expressing this property is a straight line almost parallel with the temperature axis from the inversion point of 573°.3 to 1,500° C.

The new work has also developed the law that the relative change in the rotation is practically the same, no matter what may be the color of the light passed through the quartz crystal. The so-called rotation dispersion of quartz has therefore been proved to be the same for all wave lengths at all temperatures up to the inversion point. As stated in last year's report, the Bureau's polarimetric measurements are the first precision measurements ever made at high temperatures. The progress made in these studies during the past year has made definite a new line of attack for many unsolved problems.

Adjustment and Standardization of Polariscopes.

The Bureau has inaugurated the work of adjusting polariscopes in addition to that incident to their standardization. This has become necessary owing to the fact that the sugar industry, as well as educational and research institutions, have been unable for some time to obtain new polariscopes or to get those that they have, which are out of order, put in serviceable condition.

Owing to the sudden expansion in the sugar industry, it became necessary by war conditions to resort to the use of discarded instruments. Many of these instruments have a different basis of calibration from those of the newer and recognized types. The Bureau has constantly been consulted in regard to the use of these instruments and has been able to render an important service in this respect.

In addition to the above-mentioned class of instruments, a second class has been brought out of retirement. The latter are of recognized types and are excellent instruments for the manufacturers' and refiners' use. They are, however, useless to them owing to the fact that the optical parts are out of adjustment. In many instances it is found that nicols need recementing or need to be ground and polished or cemented in their sleeves; quartz wedges are often out of alignment or pressure may have developed on the wedges, etc. An instrument which has developed any of these defects is necessarily rendered useless until they have been corrected.

During the year the Bureau has adjusted and standardized 39 polariscopes, thus putting them in condition to render good service. To bring about this desirable end required considerable preliminary study and experimental work. The middle of the fiscal year had, therefore, arrived before the Bureau was ready to receive instruments in these classes. However, the preliminary work was so successful that 39 instruments were all handled in the latter half of the year. The scales of all polariscopes that have been sent to the Bureau have been calibrated and certificates have been issued, based on the now widely accepted Bureau of Standards' determination of the international sugar scale.

Testing of Quartz Control Plates.

Quartz control plates are indispensable for the accurate daily checking of saccharimeters. Eleven of these plates were tested and certified for various sugar companies. Four, which were improperly mounted in wax, were removed from their original mounts and remounted 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 have heretofore been imported from Europe, it has been impossible to secure any for some time. With the idea 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 or improperly mounted plates in a manner to make them serviceable. The values of a number of the Bureau's standard plates have been redetermined and found to be in good agreement with the values previously assigned them.

Evaluation of the Clerget Constant.

Sugar, in every stage of its manufacture except the final one, occurs in combination with other optically active substances; that is, substances which affect the polariscope in the same manner as sugar itself. Therefore, from a single observation on the polariscope, it is impossible to estimate the percentage of sugar. If, however, the polariscope effect or rotation of the impurities is maintained constant, and the sugar is converted into other sugars (invert sugar) by the action of acid, the change of rotation is a measure of the quantity of sugar present. Thus the magnitude of this change of rotation when pure sugar is used is of fundamental importance and the value is known as the Clerget constant. The value of the constant which is now in general use throughout the world is 142.66—that is 100—the rotation of sugar, plus 32.66, the rotation of invert sugar, plus 10, a temperature correction.

During the previous year, the velocity of inversion was determined and it was found that the time which the sugar was exposed in the prevailing methods to the action of acid was excessive. The data obtained in this work made it possible to measure, under the proper conditions of time and temperature, the value of the Clerget constant. The rotation of invert sugar was found to be 33.25, instead of 32.66. This error of nearly 2 per cent affects the value of the total constant by one-half per cent and has appeared in analyses for the past 30 years.

The research has also shown that many other sources of error may be eliminated. These errors are caused by lack of constancy of the nonsugars. Three general methods of analysis have been proposed—one applicable to all substances, one applicable to beet products which are free from invert sugar, and one applicable to cane products. The value of the Clerget constant has been correlated with acid of varying strengths and with neutral salts formed by neutralization of the acids.

Solubility of Sugar and the Causes of Molasses Formation.

The greatly increased solubility of sugar in the presence of salts results in the formation of molasses, from which no granulated sugar may be obtained by crystallization. At every stage of the manufacture the crystallization is affected by the presence of salts. The study of these solubilities is therefore of technical and scientific importance.

During the past year experiments have been made on the relative effects of sodium and potassium salts in high concentration on the solubility of sugar. These two metals predominate in the products of the sugar industry. The results have shown quantitatively the great influence which the presence of the salts exerts.

In continuing the research experiments will be made on the effect of increased temperature and of a great variety of inorganic impurities which occur in beet and cane juices.

Proposed Change in the Normal Sugar Weight.

During the past year a movement has been started by American sugar chemists to change the normal weight of sugar from the 26 grams, which is now in nearly general use throughout the world, to 20 grams. If this new basis is adopted, the investigation started in the previous year on the change of rotation of sugar in altered concentrations becomes of pressing importance. Some measurements have already been made, and, in response to a general request from sugar analysts, the restandardization is being carried out as rapidly as possible.

One Hundred-Degree Point of the Saccharimeter Scale.

During the past year the Bureau has been standardizing all saccharimeters to conform to the new value of the 100-degree sugar point which was discussed in the previous report. The investigation on this subject in the Bureau disclosed an error of over one-tenth of a per cent. Considering the precision with which the modern saccharimeter is used, this error is relatively a very large one and represents a very large sum of money in the buying and selling of sugars, as well as in the collection of the revenue on imported sugars. The previously accepted determination of the 100-degree point was made at the Sugar Institute in Berlin.

International agreement on this constant is a matter of great importance, and the Bureau delayed correcting the existing error in standardizing the saccharimeters and control plates submitted for test until it seemed almost hopeless to secure such international agreement in the near future. Saccharimeters standardized according to the new value have been giving excellent results and have been thoroughly satisfactory. Many industrial concerns have sent apparatus to the Bureau to be standardized merely to get their equipment on a correct scientific basis.

Tested Supplies for United States Customs Laboratories.

The abnormally heavy importations of sugar and molasses during the past year have again emphasized the necessity of having reserve supplies of all standard apparatus used in the customs laboratories available. The situation relative to these supplies has been a most difficult one, owing to the unusual demands for additional equipment and owing to the difficulty in securing suitable supplies from the manufacturers. A customs laboratory is likely to require additional equipment at any moment. It is not feasible for each laboratory to carry sufficient reserve stock of all supplies that might be needed. The delay incidental to their purchase and the delivery by the manufacturer and the time necessary to standardize at the Bureau are often embarrassing. The most logical solution of the difficulty seems to be a storeroom at the Bureau in which tested supplies for the Customs Service can be held in reserve and shipped at a few hours' notice, as needed. Preliminary steps have been taken to bring this about.

Customs Laboratory at Boston.

When the construction of a new building for the United States Appraiser of Merchandise at Boston was authorized, advantage was taken of the opportunity to provide suitable quarters for the installation of a modern customs laboratory. The Bureau was called upon by the Supervising Architect's office to draw up plans for this laboratory. It was therefore possible to arrange a distribution of space which was far superior to what could have been done had the installation taken place in a building already constructed. Advantage was taken of the opportunity to make the laboratory a model of its kind, with all new, modern equipment. It has now been in operation for several months and has proven satisfactory in every respect.

Supervision of Customs Laboratories of the Treasury Department.

For several years the volume of work which the sugar laboratories of the Customs Service have been called upon to perform has been steadily increasing. This has occurred in the face of continuously decreasing importations of other commodities. The importations for domestic consumption during the past year have been the heaviest on record. In addition, Europe has been, to a great extent, supplied with sugar from Cuba and the West Indies which was purchased under an arrangement whereby it was to be refined in the United States. Since there is no provision in law whereby sugar can be imported into the United States and refined in bond with the object of exporting the finished product, it has been necessary to collect revenue on all the raw sugars destined for Europe. It has therefore been necessary to resort to every possible means in this emergency to increase the amount of testing done. Fortunately, this desirable result has been accomplished without perceptible deterioration in the quality of the work. The percentage accuracy of the tests has been successfully maintained at the prewar basis.

Considerable quantities of important new equipment have been added to the customs laboratories, and the work of assisting the Treasury Department in improving the personnel and efficiency has been continued.

Pure Sugars for Miscellaneous Purposes.

The Bureau issues sucrose as a standard sample. Since it furnishes a source of pure carbon, and since its fuel value is accurately known, it is widely used as a calorimetric standard in the analysis of coal. It is also used as a saccharimeter standard as a source of pure invert sugar for use as a standard in sugar analysis and for other miscellaneous purposes. Dextrose, in highly purified form, is also used as a "reducing" sugar standard in sugar analysis.

Purified dextrose is also used in bacteriological work in differentiating bacteria. The Bureau supplies it to the Medical Supply Depot for use in this work in the United States Army. Equipment is to be installed at the Bureau capable of handling relatively large quantities of material, and it will then be possible to supply both sucrose and dextrose in considerable quantities.

Sugar and Molasses at Southern Ports.

The abnormally heavy importations of sugar and molasses through southern ports were continued during the year. The scarcity of ocean tonnage which became manifest over a year ago has continued, with the result that the importations appear at the most convenient port of entry regardless of whether the Customs Service of the Treasury Department has facilities for collecting the revenue at that port.

The laboratory which the Bureau has installed at the port of Savannah has been giving excellent results and has relieved the situation to a considerable extent. The Government's inability to equip new laboratories at Galveston and Key West has resulted in still further crowding the already overworked customs laboratory at New Orleans. It is hoped that it will be possible to relieve this condition at an early date.

Standard Samples.

During the past year 95 standard samples of sucrose and 16 samples of dextrose were distributed. These materials are used principally for industrial and scientific purposes.

Polarimetric Testing.

The Bureau continues to test large numbers of polariscope-tube cover glasses for optical homogeneity. All glasses tested were of American manufacture. Polariscope tubes, sugar weights, hydrometers, volumetric apparatus, etc., were purchased for the Treasury Department and tested.

Polarimetric Tests of Raw Sugar.

The Bureau has supervision of the sugar testing in the Customs Service, Treasury Department. In this connection, 1,509 exchange samples of raw sugar for control purposes were tested. Approximately 50 per cent were direct polariscope determinations of the quantity of sucrose present, and the remainder were tested for the percentage of moisture in addition to the sucrose content.

Testing of Molasses.

In view of controversies arising between buyer and seller of blackstrap molasses in regard to the quality of the same, the Bureau has consented to make referee analyses in a number of important cases. Sixty-one such analyses have been made during the past year. Whenever the work will permit, the Bureau will continue to act in this capacity.

Filtration of Sugar Solutions.

The separation of solids from sugar solutions has become a large factor in the manufacture of sugar, due to the constant increase in the cost of labor and of the filter cloths. The tendency now is toward mechanical means which separates the bulk of the solids, thus requiring less to be removed by cloth filters. To aid in the development of mechanical separation, the Bureau has, in its work on this problem, so related the various factors which influence mechanical separation that the behavior of the solid can be predicted over a wide range of varying conditions.

Beet Molasses.

The middle western beet-sugar factories are troubled with a material appearing in the manufacturing processes which is optically active and forms solutions of extreme viscosity. The removal of sugar from solutions containing this unknown material is thereby rendered difficult. The Bureau has under way the identification and investigation of manufacturing processes to remove this material.

Color of Sugars and Sirups.

There has been a great deal of confusion in the evaluation of the color of the various sugar products. The polarimetry and colorimetry sections of the Bureau have investigated and developed a method of exactly defining the value of the color presnt, and a report will be published on this important subject in the immediate future.

Standardization of Methods of Sugar Manufacture.

The demands upon the Bureau for research work in connection with the standardization of the processes of manufacture of sugar have been so insistent that a section devoted to this work has been established. The work has received the hearty support of the various manufacturing interests. A number of research problems, in which the unusual facilities of the Bureau are particularly applicable, are now well under way.

Molasses Density.

During the past few years the value of molasses, as well as the quantity consumed, has greatly increased. The determination of the density of the material has necessarily likewise risen in importance, the value being predicated to a considerable degree upon the density.

The Bureau has developed a picnometer in the use of which entrapped air can be removed and the density determined with greater precision than heretofore.

Definitions and Specifications of Commercial Sugars.

At the present time about 40 varieties of sugar enter into direct consumption in the United States. A number of these are more or less similar, but, being made by different concerns, are sold under different trade names. They range in quality and color from the best grade of white granulated and cube sugars to the soft, dark-brown sugar.

It has long been an open question as to whether it would be practicable to prepare specifications and definitions of these sugars which would make possible their accurate identification. The trade names give little or no indication of the character of the sugar. During the year several hundred samples of these sugars have been received by the Bureau, and a systematic classification is being attempted by means of chemical analysis, moisture content, color, and numerous other chemical and physical properties.

The investigation is necessarily an extensive one, requiring much time for its completion. The results so far secured have been satisfactory. Suitable definitions and specifications now seem possible, and, if they can be accurately prepared, the result will be a matter of great importance to both the sugar manufacturer and the general public.

COLORIMETRY.

(Measurement of the factors determining color; the optical transmissive and reflective properties of materials; ultra-violet and visual spectrophotometry; standardization of colorimetric nomenclature; development of methods and instruments for colorimetry; color grading of light sources and materials.)

Colorimetry is the measurement of the physical quantities which serve to specify color. Color is properly defined as a sensation. The ordinary stimulus of this sensation is light. Colorimetry, therefore, deals with measurements relating to light. The color of a substance under prescribed conditions is defined as the color produced by the light reflected or transmitted by it. The color of light is specified by its frequencies (or wave lengths), the relative intensities of the component frequencies, and their total intensity. The color white is commonly produced by light of all frequencies between about 400 and 750 vibrations per trillionth of one second (wave length, 750 to 400 millimicrons), in certain relative proportions, as they exist approximately in daylight. In general, light in which the component frequencies occur in different proportions than these causes a color other than white, and this color may be specified by these relative intensities and the total intensity. These ratios and intensities are measured by spectrophotometry and photometry, which are thus the basis of colorimetry. There are also various types of colorimeters by which light of specified frequencies is mixed in measured proportions to produce a color matching the color being tested. 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.

Present Status of the Color-Standards Investigation.

For information relative to the nature and scope of the color-standards investigation, reference is made to the Annual Report of the Director, Bureau of Standards, 1918, p. 92. During the year progress has been made on each section of the work there outlined as the work which was being undertaken by the Bureau. Particular features of this work will be noted in the following paragraphs. The attention given to military investigations and tests during the two years past has greatly delayed progress on this investigation. On this account the investigation is about one year behind the stage it would have reached had the war not intervened. This delayed work has now been actively resumed, and every effort is being made to prosecute it with all possible speed.

The work now actively in progress or to which immediate attention will be given this year may be classified as follows: Continued improvement and extension of spectrophotometric methods; standardization of colorimetric nomenclature; investigation of "white light" and "average daylight"; application of rotary dispersion to colorimetrey; investigation of the spectral transmissivity of dyes (in cooperation with Bureau of Chemistry); investigation of spectral transmissivity of colored inorganic-salt solutions; investigation of colored railway-signal glasses; development of technologic methods for the commercial color grading of materials.

Extension and Improvement of Spectrophotometric Methods.

As has been repeatedly emphasized in previous reports, the physical basis of colorimetry is spectrophotometry and efforts to improve, systematize, and simplify spectrophotometric methods have been continued. (See Ann. Reps., 1916, p. 87; 1917, p. 86; 1918, p. 93.) Definite accomplishments marking progress in this work during the year may be noted as follows:

Visual Spectrophotometry.—The improved illumination apparatus for the Koenig-Martens spectrophotometer, mentioned as under construction in last year's report, has been actually installed and used in extensive work. This apparatus provides for measurement of both spectral transmission and diffuse spectral reflection by very small and quickly made changes in arrangement. Both incandescent and mercury vapor lamps are installed in the apparatus, thus providing for illumination either by heterogeneous or homogeneous light. It gives a practically perfect photometric field, and is proving altogether very satisfactory in practice. Further thorough and detailed investigation of the precision and accuracy of measurement is in progress. A Bureau of Standards technologic paper describing this apparatus is in course of preparation.

A new spectrophotometer for liquids (oils, dye solutions, etc.) employing the principle of variation of thickness is partly designed. Measurements already made by this principle with an instrument made in the Bureau's shop are very satisfactory, and the method when perfected promises to afford a great improvement in the measurement of the transmissivity of liquids. It is planned to use such an instrument in color grading oils and in the investigation of dyes.

Photo-electric Spectrophotometry.—The new photo-electric apparatus mentioned in last year's report has been used with great satisfaction in many tests. A brief description of this apparatus has been published (Jour. Op. Soc. of Am., January–March, 1919); and a complete detailed description of it is now in press (Bureau of Standards scientific paper). Changes are being made by which a thermopile and galvanometer (thermoelectric method) may be used with the same apparatus. When it is thus amplified the apparatus will enable accurate measurements to be made over a wave-length range from about 380 millimicrons in the ultra-violet, all through the visible to about 1,000 millimicrons in the infra-red.

Photographic Spectrophotometry.—The Hilger sector apparatus has been used in many tests. Minor improvements have been made in the permanent installation.

Correlation and Comparison of Methods.—Each of the three methods mentioned above has its strong and weak points. Used together they serve to supplement each other in a very satisfactory way, for where one is weak another is strong. For very short wave length (less than 380 millimicrons, ultra-violet) only the photographic is used. For wave lengths between 500 and 380, both the photographic and photo-electric are applicable. The visual method is good between about 650 and 450, but more or less unsatisfactory beyond these limits. In the regions where two or more methods overlap they have been found to check very satisfactorily in careful work. The thermo-electric method when perfected will complete our requirements by providing means of measurement in the red and near infra-red (wave length 600 to 1,000 millimicrons).

Temperature Control in Spectral Transmission Measurements.—The light transmission of a substance is, in general, a function of its temperature. It is therefore necessary to make measurements for accurate work in many cases at a specified temperature, although the temperature regulation need not be very accurate. Thermostats have been designed to control the temperature of the sample in connection with the Koenig-Martens, the Hilger sector, and the Gibson photo-electric apparatus. These thermostats are now being permanently installed in connection with this apparatus. For the present we are only interested in ordinary temperatures, and these thermostats are therefore designed to operate only at temperatures from about 10° C. to 50° C. and will usually be used between 15° and 35°.

Summary.—The colorimetric section now has working equipment permanently installed to make spectral transmission and diffuse reflection measurements on short notice by different methods in a routine way, on a range of wave length from about 220 millimicrons to about 700 millimicrons, and apparatus for making transmission measurements at specified temperature is now being installed. Further study of accuracy and further efforts for improvement are being made, and the thermoelectric method will extend the range to about 1,000 millimicrons.

Development of Technologic Methods for Commercial Color Grading of Materials.

From a utilitarian point of view, the end and purpose of the color-standards investigation is the development of methods and apparatus to provide for the routine technical color grading of materials in which color is a point of interest. This is the reason the industries urge the Bureau to do the work, and this is, in fact, the reason money is appropriated for it. Those in active charge of the work know that this end can only be attained by founding the method on accurate, thorough knowledge of the very recondite and, to the layman, unfamiliar facts and phenomena involved. They are also, however, keenly aware of the need of applying this knowledge in a practical way to the practical problems presented. Time, thought, and effort are therefore divided between fundamental research and its application. Below are noted some of the current problems on which progress has been made and, in some cases, definitive reports issued during the year.

Color Grading of Cottonseed Oil.—An investigation of the color of cottonseed oil has been in progress at the Bureau for a number of years. An important feature of this work has been the determination of the spectral transmissivities of a large number of representative samples. The Bureau has long been of the opinion that the simplest, the most definite, and, in the end, the most useful and significant method of color grading this oil would be in terms of its transmissivity for certain selected wave lengths. However, a requirement to be met was means for the translation of values on any new scale into approximate values on the Lovibond color scale, which has been in use in the cottonseed oil industry for perhaps 20 or 30 years. Investigation during the past year has led to the discovery of a simple relation which makes possible the preparation of such a conversion table of transmissivity ratios and Lovibond values for oils near "prime" in color. Recommendations on the color grading of cottonseed oil which were final and definitive, in so far as fundamental principles were concerned, were submitted to the Convention of Cotton Products Analysts, by the Bureau's representative, New Orleans, May 17, 1919. (Cotton Oil Press, July, 1919, pp. 86–88.) The essential features of these recommendations are as follows

1. Color grading in terms of colored glasses or other material standards should be discontinued except in certain particular cases where it may be desirable on account of convenience in quick reference or where apparatus for grading by the method proposed below is not available. The reasons for this recommendation are:

(*a*) Such standards are difficult to obtain and difficult to duplicate.

(*b*) The calibration and certification of a large number of them involves an immense amount of labor.

(*c*) They are of questionable permanency.

(*d*) The number of them necessary for a complete scale makes great trouble in practice.

2. The oil should be graded in terms of its transmissivity for monochromatic light of certain specified wave lengths.

3. Oil nearly "prime" in color should be graded in terms of its transmissivity for 1 decimeter for light of two-wave lengths, viz, 546 millimicrons and 578 millimicrons.

Making use of these measured transmissivities, it will be possible to express completely and uniquely both the quality (hue and saturation) and the brilliance of the color of the oil.

The Bureau will undertake to provide two conversion tables, viz:

(*a*) A table giving values on the Bureau of Standards' average Lovibond scale in terms of the ratios of the transmissivities for wave lengths 546 and 578 millimicrons to an accuracy limited only by the essential uncertainty of the Lovibond scale.

(*b*) A table giving the total transmissivity for average sunlight (brilliance of oil) in terms of the transmissivity for wave length 578 millimicrons.

The system of grading in terms of transmissivities possesses the following advantages:

1. It expresses an essential property of the oil itself. It is quite possible that the chemist in the future will find such data of much interest aside from its use in specifying color.

2. It is independent of any question of the observer's color vision. The measurements can be made just as well by a color-blind observer as by one having normal vision. This is by no means an unimportant consideration when it is remembered that railroad statistics show that 1 man in 20 is color blind.

3. It is physically simple and capable of precise specification in easily reproducible units and conditions, thus eliminating arbitrary, ill-defined, nonreproducible standards.

New apparatus is now being designed to provide for putting these recommendations into practical effect, and further cooperative work on details will be carried out in cooperation with the Society of Cotton Products Analysts.

Color Grading of "Pyralin Ivory" for Du Pont de Nemours & Co.—At the request of Du Pont de Nemours & Co., a minor investigation of the color of their product "pyralin ivory" has been made. Diffuse spectral reflection curves for a number of samples were made and a report forwarded to the company June 27, 1919.

Color Grading of Sugar Solutions.—Considerable work has been done on investigation of the spectral transmissivity of sugar solutions for samples from various sources and different concentrations. This work is in progress, and no reports have as yet been issued. Attention is being given to the formulation of suitable methods for routine work, and it appears at present that the solution of this problem will be comparatively simple.

Color Grading of Various Materials.—The materials which it is desired to grade by color in commerce are almost innumerable, including paints, dyes, inks, textiles, paper, flour, soap, tobacco, butter, and many other things. The Bureau's correspondence shows inquiries for information and advice on these problems from the most varied sources. In practically dealing with these problems general principles nearly always have to be specialized, and each problem requires individual treatment. Up to the present the Bureau has been able to give very few of these problems adequate attention.

A method for color grading of butter and oleomargarine was published several years ago (B. S. Tech. Paper No. 92), and since then this matter has demanded no further attention except in making a few tests in terms of the specification therein given.

Paper grading has been given a great deal of attention in regard to its transmission, diffuse reflection, and glaze. Previous publications (B. S. Circular No. 63 and Trans. Am. Cer. Soc., vol. 17, Detroit convention, 1915) have dealt with the paper problem in a partial way. Further work has been done and progress made, but this work has not yet reached the stage for a definite report.

Standardization of Colorimetric Nomenclature.

One of the primary and urgent needs of colorimetry is an established and recognized nomenclature, as well as systems of units, standards, and symbols. During the year progress has been made in the formulation and standardization of these matters in the work of the colorimetric section, but it is necessary that general agreement be reached with all concerned. Action has been taken to bring this about, the Optical Society of America having formed, in January, 1919, a committee for this purpose with the chief of the Bureau's colorimetric section as chairman. It is expected that this committee will make a report in December, 1919.

Data on the Spectral Transmission of Various Glasses in the Visible and Ultra-Violet.

The spectral transmissions of various colored glasses are a matter of great interest in colorimetric and related work, as they may serve as secondary standards and as "filters" for selecting light of particular colors. There has been need for a compilation of data on available glasses.

During the last three years the spectral transmissions of a great number and variety of glasses have been measured throughout the ultra-violet and visible. These data have now been collected and a paper on this subject is in course of publication (Bureau of Standards technical paper). The transmissions for the visible and ultra-violet of 87 samples of glass, representing over 50 different kinds, mostly colored, which are useful for various purposes, are given in this paper. The glasses listed are representative of what may be obtained to-day on the American market, and include also some of foreign make which could be obtained before the war. It is thus possible to make comparison of the relative merits of foreign and American glass and see in what respects the latter may duplicate or improve upon the former.

All of the glasses listed in this paper, so far as it was possible to get values, were measured photographically and visually and in most cases photoelectrically. The photographic (Hilger sector photometer with quartz spectrograph) method may be used from 230 to 500 millimicrons, the photoelectric null method from 380 to 600, and the visual (Koenig-Martens spectrophotometer) from 436 to 720. The data are presented in the form of transmission curves extending from 720 millimicrons throughout the visible and ultra-violet as far as the specimens have any appreciable transmission. The methods overlap to such an extent that when all are used extremely reliable curves may be obtained. With possibly a few exceptions, therefore, the curves as given are considered accurate within 0.02 on the transmission scale of 0.00 to 1.00, and in many cases, especially at low transmissions and in the better specimens, the uncertainty is definitely less than this.

For each specimen are given the transmission curve, the thickness, the trade name or designation, and the maker or dealer. In each figure also is given the relative visibility curve for the average human eye. An inspection of the curves must be made by those interested, inasmuch as this kind of data can not be summarized.

Various practical uses to which these glasses are put are indicated, such as ultra-violet signaling, railway signaling, improvement of visibility both for visual and photographic work, protection of the eyes, and selective ray filters. Of special value in scientific work is their use as filters to obtain monochromatic light from mercury, helium, or hydrogen lamps. Transmission curves of such filters are given.

Investigation of Railway-Signal Glasses.

As is well known, colored lights are almost universally used on railways to indicate "danger," "stop," "safety," "clear," "caution," etc. It is by the guidance of such lights that the engineer operates his train. These colored lights are largely obtained by placing colored glasses in front of oil or electric lamps. The standards for these glasses should be specified in terms of spectral transmission, and indeed the standards of the Railway Signal Association are so specified. It is a matter of prime importance to public safety that the proper standards be maintained and adhered to rather closely in practice, which means a certain amount of spectrophotometric testing. Appreciating this, the Pennsylvania Railroad has frequently required such tests of this Bureau, and has lately requested that the Bureau undertake a more extensive and thorough investigation of makers' working standards. It is to be understood that, while specifications are written in terms of spectral transmission, not every glass to be put to use can or need be tested in these terms. The manufacturers keep certain particular glasses as working standards. Question has been raised as to the authenticity and uniformity of these working standards, and as the railways themselves are without spectrophotometric equipment, and therefore unable to test the glasses delivered, the question has accordingly been referred to the Bureau. Copies of the makers' working standards have been obtained and are now in course of investigation. It is expected that a report will be published within a few months (Bureau of Standards technical paper).

Investigation of Eye-Protective Glasses.

Many glasses have been recommended and extensively advertised to absorb injurious radiant energy, and so protect the eyes when worn as spectacles or goggles. However, physiologists and oculists desiring to conduct experiments to determine the value of such glasses have little to guide them in their selections except the claims of makers and sales agents. In order to experiment or prescribe intelligently, it is obviously necessary that authentic and authoritative data should be available on the spectral transmission of the various glasses which are being commercially promoted as valuable in protecting the eye from harmful radiant energy. Feeling this need of data, Dr. W. C. Posey, chairman of the committee on hygiene of the eye, American Medical Association, formally requested this Bureau to make an investigation of the spectral transmission of these glasses.

The report on this investigation has now been published. (Bureau of Standards Technical Paper No. 119.) In this paper are given the results on 82 samples of eye-protective glasses which are at present on the American market, the list including various shades of glasses sold under the following trade names: Akopos, Amber, Amethyst, Arkweld, Blue, Chlorophile, Chromatic Test, Cobalt Blue, Crookes, Electric Smoke, Euphos, Fieuzal, Hallauer, Luxfel, Noviol, Noviweld, Pfund, Rifleite, Saniweld, Smoke, and others, including heat-absorbing, welding, and colorless crown glasses. Some of these specimens are of unknown origin, glasses which have been marketed for years under more or less well-recognized trade names. The data given show what may be obtained under one of these names;

but, as there are usually so many different shades of the same kind of glass marketed under the single trade name, it can not be expected that duplicates can be obtained merely by ordering by name. However, most of the specimens, especially those of American manufacture, are designated by shade—that is, " A," " B," etc.—as well as by trade name or by number; and in this case it is expected that approximately duplicate samples can be obtained. Yet in no case, probably, is the designation a sufficient specification; but the oculist or buyer, guided by the data given in this paper, may now prescribe or order glasses of specified spectral transmission, acceptance being subject to test.

By means of tables and curves the results of the investigation have been presented in such a way that the information desired may be quickly obtainable. For each specimen is given: The trade name (including the shade designation) under which it is marketed; the company from which it may be obtained; the approximate color; the thickness, the samples being from 1.42 millimeters to 3.20 millimeters thick, that ordinarily used in spectacle lenses. The per cent transmission curve from 230 to 710 millimicrons (in each figure there is also given for comparison the transmission curve of a sample of colorless crown glass and the visibility curve for the average human eye); the total transmission for light of equal energy at all wave lengths, computed from the visibility curve and the transmission curve.

Precision Determination of Spectral Transmission of Visibility Solution.

A ray filter or screen which transmits energy of different wave lengths in proportion to its visibility is known as a " visibility filter." A solution of cupric chloride, cobalt-ammonium sulphate, potassium chromate, and nitric acid in water in a glass cell produces approximately this result. Such filters are necessary in physical photometry. The spectral transmission of such a filter must be known.

At the request of Dr. H. E. Ives, the spectral transmission of a solution made according to a formula submitted by him has been determined. The solution was prepared by the chemical division at the Bureau according to the formula submitted: Cupric chloride ($Cu\ Cl_2 . 2H_2O$), 61.25g.; cobalt-ammonium sulphate ($Co\ SO_4 . (NH_4)_2\ SO_4 . 6H_2O$), 14.5g.; potassium chromate ($K_2\ Cr\ O_4$), 1.9g.; nitric acid (Sp. Gr. at 15°, 1.05), 18.0 centimeter; water to total volume of 1 liter. The ratio of the transmission of a 1.03-centimeter glass cell containing this solution to the transmission of the same cell filled with distilled water was determined with great care by both the visual and photoelectric methods, the total wave-length interval covered being about 440 to 670 millimicrons. A complete detailed report was issued to Dr. Ives, March 22, 1919, but has not as yet been published otherwise. It is expected that publication may be made later in suitable connection. In the meantime the data may be obtained on application to the Bureau by any one interested.

Calibration of " Munsell Color Standards."

The Munsell Color System (Wadsworth, Howland & Co., Boston, Mass., and Munsell Color Co., New York) has attained considerable importance and recognition in art, and particularly in color printing.

This system has many good features, but, unfortunately, it was developed and put into practice without adequate fundamental standardization. Lately the Munsell Color Co. has submitted its standards to the Bureau for calibration. The spectral diffuse-reflection curves of 24 samples have been determined, and a complete report made to the company. This report has not been published, but the data may be obtained from the Bureau by anyone interested in it.

As one result of the calibration, it appears that the Munsell "value" numbers are not proportional to diffuse reflection, as seems to be understood in Munsell's Color Notation, but actually the squares of these numbers are strictly proportional to diffuse reflection. This suggests some confusion in the fundamental concepts and basis of the system. The diffuse reflections of the Munsell value scale do not form a geometrical series as in a "natural" scale of value.

New Radiation Formula.

The energy given out by a complete radiator is a complex function of the wave length and the temperature of the radiator. Many formulas have previously been proposed to express this complicated relation. The earlier ones, due to Wien and Rayleigh, were long ago found to be only approximate, not fully representing the actual experimental facts. A formula representing the experimental data much more closely was later devised by Planck. In working over the old experimental data in connection with his colorimetric work a member of the colorimetry section has discovered an empiric relation of a form quite different from that of Planck and representing the data apparently even better than Planck's formula. The equation or formula representing this relation has been published (Jour. Op. Soc. of Am., January–March, 1919, and Phy. Rev. (2), 13, 314, 1919) and has proved to be of some interest.

Colorimetric and Related Tests.

Twenty-six test reports giving data on about 90 specimens or pieces have been issued. The data given were for the most part spectral transmission in the visible and ultra-violet, but included also reflection measurements, as well as relative spectral-energy distribution in light sources. Eleven of these reports were on military tests for the Army, Navy, and National Research Council.

Information Furnished on Color, Colorimetry, and Related Subjects.

Information in response to requests has been furnished on color, colorimetry, colorimetric apparatus, and related subjects, both by letter and personal conference with visitors. About 90 such letters of information were sent and about 60 such visitors given oral information.

Military Investigations.

As mentioned above, a great deal of time has been taken from the work on colorimetry proper to undertake military investigations. This was mentioned in last year's report; but at that time it was not permissible to mention these investigations specifically. The occasion for secrecy now having passed, some account of this work may properly be given. It was for the most part done in the preceding fiscal year, although some of it has extended into the year of this report.

Ultra-Violet Signaling.

Several months before the entry of the United States into the war the Bureau of Standards was requested to advise the Navy as to the selection and specification of a lamp to be used as a stern light so designed that it would be visible to other ships of the same squadron at 1,000 yards astern, while not visible at greater distances and not easily picked up by enemy ships.

This request suggested the possibility of screening the source with a filter transparent to ultra-violet, while opaque to the visible and observing it with a fluorescent detector. Experiments made at the Bureau, February to May, 1917, showed in general the feasibility of this idea, and a letter to this effect was delivered to Admiral R. S. Griffin, June 1, 1917. A detailed technical report was made to Admiral Griffin, March 6, 1918. A paper on this subject was presented to the American Physical Society, Washington, April 26, 1919, and it is expected that an abstract of this paper will be published in the Physical Review.

Methods of ultra-violet signaling were also developed independently by others outside of the Bureau about the same time and the Bureau later assisted these experimenters by performance of tests and loans of apparatus.

Visual Detection of Submarines.

Immediately after the entry of the United States into the war the detection of the submarine was perhaps the most pressing of all war problems. In the course of time various means of detection were developed, some of them highly technical and complicated. At the outset it appeared that the simplest means of detection—viz, sighting the submarine or its periscope—should not be neglected, but developed to its highest possible efficiency. The National Research Council appointed a committee, on which the Bureau of Standards was represented, to consider and make recommendations on this subject, in particular in regard to aids to vision, methods of observation, and development of the lookout service.

The report of this committee (dated July 13, 1917) was prepared at the Bureau and transmitted to the National Research Council July 23, 1917. A supplemental report was made October 6, 1917.

Chromatically Concealed Insignia and Detection of Chromatic Camouflage.

Owing to the fact that different spectral distributions of light may give the same color, it is possible to have samples accurately color matched as examined by the unaided eye in daylight, and still show glaring chromatic contrast when examined through suitable light filters (colored glasses, etc.). This circumstance was a source of danger to the camouflage artist. For example, a fabric might be dyed green to closely match green foliage, and through a properly chosen filter it might appear bright red on a dark green or black background of normally green foliage. Indeed, it might be about as conspicuous as a fire at night. On the other hand, it might, through another filter, appear dark on a bright-red background of normally green foliage.

At the request of the War Department, the Bureau made several tests of materials in this respect and was able to recommend dyes and select fabrics to overcome this difficulty.

The Bureau did not itself undertake a comprehensive and unified investigation of the subject of "camouflage." However, a great deal of work bearing on it was done at the request and instigation of others working on these subjects. A great deal of oral information on ray filters, spectral transmission, and reflection and chromatic camouflage, often illustrated by experimental demonstration, was given to officers of the Army and Navy and representatives of the National Research Council. Ray filters were loaned from stock, and others were made to order of prescribed properties and supplied to the applicants for them.

The Bureau was also asked to investigate the practical possibilities of chromatically concealed insignia; that is, insignia woven, painted, or made in such a way that they would be invisible to the unaided eye in daylight and be rendered visible by examination through properly selected filters. Many combinations of dyed fabrics were prepared which were nearly or quite indistinguishable to the unaided eye, but showed remarkable color differences when examined through suitable filters. These were exhibited and explained to numerous representatives of the War and Navy Departments. An exhibit of some of these was made in connection with the American Physical Society exhibit at the Bureau, April 25–26, 1919.

Publications.

Numerous reports were issued. Some of them were of no interest except in the particular circumstances of the test at the time. Those which may be of some permanent interest are listed below:

1. Letter to General Engineer Depot on Visibility of Green Tape; May 17, 1918.
2. Visual and Photographic Tests of the Visibility of Green Tape, submitted by General Engineer Depot, Bureau of Standards test No. 23667; June, 1918.
3. Visual and Photographic Tests on the Visibility of Green Tape, submitted by Office of Quartermaster General, Bureau of Standards test No. 23978; August 12, 1918.
4. A Green Cotton Dye to Simulate Green Foliage; November 12, 1918.
5. Spectral Transmission of Eight Aviator Goggles from England, submitted by National Research Council (subsequently identified as "Brock goggles"); June 13, 1918.
6. Spectral Transmission of Screen Prepared by C. E. K. Mees to Duplicate Brock No. 61, submitted by science and research division, Bureau of Standards test No. 24034; August 23, 1918.
7. Optical Duplication of Light Filter Known as "Brock No. 61"; September 9, 1918.
8. Duplication of Light Filter Known as "Brock No. 61" (supplement to Report of September 9); September 30, 1918.
9. Spectral Transmission of Two Pairs of Anticamouflage Goggles, submitted by Navy Department, Bureau of Standards test No. 23662; June 22, 1918.
10. Dichromatic Red-blue Screens Prepared by Bureau of Standards for Navy Department; supplement to Bureau of Standards test No. 23662; July 9, 1918.
11. Letter to Bureau of Construction and Repair, Navy, Describing Preparation of Dichromatic Filter Made to Order to Duplicate Prescribed Spectral Transmission; October 9, 1918.

12. Diffuse Reflecting Powers of 13 Samples of Painted Canvas, submitted by development branch, photographic section, Bureau of Aircraft Production, Bureau of Standards test 23880; August 30, 1918.

Optical and Photographic Methods for the Detection of Invisible Writing.

Early in the war it was suspected with more or less plausibility that German agents were using so-called "invisible inks" in their communications. The secret service agents of the Government had intercepted and held on suspicion vast quantities of correspondence, and the Bureau of Standards was asked for advice as to methods of examining this for the suspected invisible inscriptions, which, if existent, could doubtless be developed and read by suitable means. Development and supervision of chemical tests was assumed by other agencies, and this Bureau undertook only the matter of optical and photographic tests. Special apparatus was designed and constructed at the Bureau and used by the offices of the Naval and Military Intelligence. The purpose of this apparatus was to provide convenient and rapid means for the routine examination of a great number of pieces. The methods for regular routine examination were the following: (*a*) Examination in intense light at grazing incidence; (*b*) examination by regular reflection; (*c*) examination by transmitted light; (*d*) examination in extreme violet and ultra-violet light; (*e*) examination by ultra-violet photography.

The first three tests mentioned above involve essentially nothing more than specific control of the direction of illumination and the line of sight in the examination of the paper. It is a matter of common observation that faint marks, erasures, indentations, etc., on a sheet of paper can be seen much better at certain angles than at others. The apparatus for tests (*a*) and (*b*) merely provides convenient and comfortable means for the critical examination under two specific conditions, both of which greatly accentuate the appearance of irregularities in the paper surface. For test (*c*) the paper was laid on a ground glass illuminated from below. No special apparatus needed to be constructed, as an Edison mimeoscope served this purpose very well.

Methods (*d*) and (*e*) are somewhat further removed from ordinary experience, and so require more explanation.

Method (*d*) depends upon fluorescence; that is, the property which many substances possess of emitting light when excited by ultraviolet rays which themselves do not cause vision.

Inscriptions made with such substances, dissolved and used as inks, may be quite invisible in ordinary light under any kind of illumination, but show up in bright characters on the darker background of the paper when excited by ultra-violet rays. Paper itself, in common with many materials, is fluorescent in varying degree. If the ink is composed of a substance less fluorescent than the paper, or if the solvent dissolves the surface glaze, the writing will show dark on a light background. Inscriptions written with pure water may be detected in this manner on some kinds of paper.

The test is performed by allowing ultra-violet rays to fall on the paper in a dark room. The ultra-violet is obtained from a Cooper-Hewitt glass mercury lamp screened by a glass which absorbs nearly all of the light from this lamp while it transmits very freely the ultra-violet and a small amount of violet light.

Method (*e*) depends upon the fact that some substances may be so nearly the color of white paper as to produce little or no contrast when inscribed on it, while they may differ from it sufficiently in their absorption for ultra-violet as to give noticeable contrast in an ultra-violet photograph. For this purpose ultra-violet rays of wave length considerably shorter than used in the fluorescence test were employed. The quartz-mercury arc and the iron arc are suitable sources for such rays. The blue and violet light and the longer wave length ultra-violet are absorbed by an aqueous solution of nickel sulphate and gaseous chlorine in quartz cells. Since these rays are absorbed by glass, the lenses used must be made of quartz, fluorite, or other material which will transmit them.

Five illustrated technical reports on this subject were issued to the Office of Naval Intelligence during the war. Information on this subject was also given to the division of Military Intelligence. An exhibit of the apparatus used was included in the American Physical Society exhibit at the Bureau; April 25–26, 1919.

The methods developed are also of use generally in the critical examination of paper and documents. Last April the Bureau was able to decipher the name and address on a military-registration card sufficiently well to establish certain identification of the bearer after the card had been immersed in sea water with the dead body of the drowned registrant so long that it was quite illegible to ordinary observation and the body itself was completely unrecognizable.

A Method for Color Grading of Red Signal Flares.

At the request of the American University Experiment Station, a method for color grading red signal flares was developed and a report issued in July, 1918. This method had also been described in a communication to the American Physical Society and is now in course of publication (Phy. Rev.).

Searchlight Investigation.

The high-power search lamps have acquired tremendous importance in the last few years. Few data, however, are on record regarding some of the fundamental characteristics of these search lamps or bearing upon some of the fundamental problems under searchlight illumination. An investigation in cooperation with the Corps of Engineers of the Army has been carried on, using the combined facilities of the colorimetry section of the optics division and the photometry section of the electrical division at the Bureau. This work is briefly described below.

From data collected by the Bureau, two distinct types of distribution appear: That in the medium intensity arcs resembles a "rose" distribution; that in the high intensity a "cardioid" distribution.

The development of high-intensity arcs by the use of specially prepared carbons has resulted in the production of a light which is very blue relative to artificial incandescent sources. In a general investigation of searchlights, including the effectiveness and suitability of their illumination for various purposes, it appeared desirable to have at least approximate quantitative data on the color of this light.

An investigation was made by spectrophotometric and special colorimetric methods and a report was issued to the Corps of Engineers and others January 23, 1919. Another report was made to the American Physical Society April 25, 1919, and will be published in the Physical Review.

The result of these investigations may be roughly summarized by saying that the color of the light from these arcs is approximately equivalent to the light of the noon sun at Washington, although relatively more intense in the blue-violet.

The diffusion or scattering of light along the path of a searchlight beam is very important from several standpoints. The diffusion of the light out of the beam decreases the intensity of light falling upon the target. This diffused light limits the visibility of the target for an observer near the search lamp who must look through and along the beam. On the other hand, this diffusion of the light along the beam makes possible the use of the searchlights as landmarks for military and other purposes; and also facilitates the training of the beam in a given direction, particularly when combined action of two or more search lamps is desired.

Measurements have been made from various directions of the brightness of the path of the beam due to the diffusion of the light by the atmosphere. The per cent of polarized light in the diffused light has also been determined.

In order to make any conclusions as to the size and distance of a given target that may be seen in a searchlight beam, there is demanded some knowledge as to what is the minimum difference of brightness that the eye can detect. Laboratory experiments were made to collect data upon the contrast sensibility of the eye under conditions closely simulating those under actual searchlight illumination. Very definite results have been obtained.

In connection with the testing and use of search lamps the question of how much light is lost as the beam penetrates the atmosphere must be considered. It is important to know what the transmission of the atmosphere is when tests are made at great distance from the search lamp.

Very meager definite data exist upon the transmission of the atmosphere under all weather conditions—clear, hazy, foggy, rainy, etc.

It is important also to have a knowledge of the relative transmission for different-colored lights.

A method has been devised to procure relative data on the transmission of the atmosphere throughout the spectrum, and some observations have been made for a clear atmosphere, for one of rather high humidity, and for rains. Other kinds of weather could not be taken advantage of thus far. It is planned, however, to continue these observations for foggy weather.

These data are not only valuable for the searchlight engineer, but are important also in aerial and other photography and to the illuminating engineer interested in automobile head lamps, etc.

A chart has been made showing where all losses of light in the search lamp take place, and their magnitude from the moment the current flows through the arc to the time that the beam impinges upon the target.

A physical photometer is under construction for use in connection with the photometry of search-lamp arcs. On account of the high intensity of the light from arcs they are admirably adapted for the application of the physical photometer.

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.)

Effect of Striæ on Optical Glass.

An extended investigation has been conducted on the subject of striæ in optical glass and their effect on the performance of the completed optical instrument. Numerous photographs have been taken showing the degree of striation in the glass and the corresponding effect upon the definition of instruments in which the striated glass has been used. The results of the investigation made on the subject of striæ are being prepared for publication. Though difficult to give any but a photographic measure of the amount of the striæ, it may be said in general that striæ, if faint or few in number, are not very injurious in the objectives of binoculars, but considerably more so in the prisms and oculars.

Refractometer Design.

The two standard types of refractometer, an instrument for measuring refractive indices, are known as the Abbé and Pulfrich. Until recently all such instruments were made in Germany. Their Abbé type was accurate to five units in the fourth decimal place, while the Pulfrich was accurate to one or two units in the fourth. Since the beginning of the war other countries have entered the field and some little effort has also been made to develop American instruments of these two types, which would be more accurate than those of foreign manufacture.

A design for an improved type of Pulfrich refractometer, in which the scale is horizontal instead of vertical, as in the old type, has been worked out in the Bureau. The error of this instrument should be less than that of the German instrument, not greater than two units in the fifth decimal place, as compared with, say, one or two in the fourth for the German instrument.

An Abbé type of refractometer has been designed recently by an American manufacturer with the aid and advice of the Bureau. The Bureau made a careful examination of the preliminary model and recommended several changes. The final instrument, when actually tested, was found to be accurate to five units in the fifth decimal place, making it the most accurate of this type which the Bureau has tested.

Circular Letter on Methods of Silvering Glass.

In response to numerous requests for information on the subject of silvering glass, a circular letter of information was prepared in which all the standard methods were collected and put into convenient form.

Camera for Photographing the Inside of a Machine-Gun Barrel.

The Machine-Gun and Small-Arms Section of the Engineering Division of the Army has been studying the deterioration of the inside of machine-gun barrels due to the action of the hot powder gases. Their practice has been to fire a few thousand rounds and then saw the barrel lengthwise. Being desirous of studying, however, the successive stages of deterioration, they requested the Bureau to devise means for examining the interior of the barrel without impairing the usefulness of the firearm. A special camera has, therefore, been designed to permit the taking of a panoramic photograph of the inside of the barrel. It is now being constructed in one of the Bureau's shops.

Night-Firing Device.

A small projection device for throwing a spot of light on a plotting board for use in connection with night firing was designed for the Ordnance Department of the Army. Two of these devices were built for this Department in the shops of the Bureau.

Condenser System.

At the request of the Medical Service of the Army, a suitable set of condenser lenses to be used with an acetylene flame for microscopic work in the field was completed and submitted to the Medical Supply Depot.

Calculation and Removal of Certain Errors in Centered Systems of Lenses.

In designing and in testing a system of lenses—e. g., for a telescope or camera—the refined calculations by trigonometric functions are not necessary for the treatment of errors of the lower orders. Those errors can be computed to first and second approximations by algebraical formulas. For this purpose tables have been devised. One set of tables with graphs to expediate a preliminary survey, has been computed and put in use—the table for eliminating spherical aberration. By means of this it is estimated that results can be obtained in one-tenth the time formerly needed. A paper soon to be published describes this work in detail.

For eliminating astigmatism a table is partly finished which will simplify the work. It is so devised that the two errors—those of spherical aberrations and of obliquity—are computed together· giving the position and curvature of both astigmatic image surfaces.

Chromatic aberration is, in practice, removed in advance of these other two errors by proper choice of focal lengths.

Testing of Optical Systems.

The Bureau was called upon to make various tests on a wide variety of optical instruments. Periscopes, small range finders, gun sights for both Army and Navy, bombing sights, in addition to the more common types of instruments, were brought to the Bureau for both test and advice. In some cases the work done has been comprehensive; in others the assistance rendered consisted simply in a short conference in which certain details of the instrument were discussed and inspected.

(*a*) *Tank sight.*—The Bureau coöperated with the Inspection Division of the Ordnance Department of the Army in the development of a tank sight. Both the consulting and the laboratory facilities of the Bureau were used freely for putting the instrument on a production basis. The range scale for it was computed at the Bureau and a representative of the optical instrument section made a special trip to Boston in connection with the production of the instrument.

(*b*) *Gun sight.*—The Bureau cooperated to a considerable extent with the Inspection Division of the Ordnance Department in the development and testing of 37-millimeter gun sights.

(*c*) *Machine-gun panoramic sight.*—A conference on the specification for the panoramic sight for machine guns was held at the Bureau on July 15, and from then on up to the time of the signing of the armistice the Engineering Division was in frequent consultation with the Bureau with reference to the specifications and performance of this instrument.

(*d*) *Periscopic alidade.*—A French periscopic alidade was sent from the Expeditionary Forces to the General Engineer Depot with the request that the instrument be copied and supplied to the American forces. The instrument was turned over to the Bureau, where its component parts were carefully measured and drawings necessary for the construction of a similar instrument furnished the Engineer depot. From these the Central Scientific Co., an American firm, made a sample instrument, which was returned to the Bureau for inspection. This instrument, after a few minor changes, was approved.

Binoculars.

A large portion of the activities of the optical-instrument section was centered upon the testing of binoculars. The Bureau was requested to perform check inspections on one out of every hundred binoculars produced for the United States Army. Special apparatus was designed and built for the rapid testing of these instruments. This testing apparatus was adopted by the Signal Corps, who borrowed a member of the Bureau staff to take charge of the Signal Corps inspectors and Bureau methods of testing at the various factories. A school for the instruction of inspectors of binoculars, lasting three weeks, was held at the Bureau during October. This was attended by 10 Signal Corps' inspectors, who were, after receiving their training, sent out to the various factories to perform acceptance tests on binoculars.

A manufacturing company undertook the manufacture of binoculars for the Signal Corps. They had considerable difficulty at first in getting the optical parts of the binoculars properly placed in the instrument and referred some of their troubles to the Bureau, which was able to be of assistance in getting this company on a production basis.

In consultation with the Bureau of Standards another company embarked on the manufacture of a new type of binocular in which the machine work is largely replaced by pressed metal parts. This company has produced a very promising binocular.

Tests extending over a period of three months were made on the lenses of six Army field glasses for the purpose of determining the rate of growth and development of blisters in the cementing compound of the lenses. In general, it was concluded that lenses with bubbles or blisters in the cement should not be used in an instrument because of the probability of the defects increasing in size, and, furthermore, that the final inspection of lenses should not take place sooner than two weeks after they have been cemented.

The United States Shipping Board, Emergency Fleet Corporation, gave orders for 1,000 binoculars to be used on board the merchant marine, and requested the Bureau to perform acceptance tests on each instrument. Something over 1,500 binoculars were tested in order to secure the 1,000 acceptable instruments. The two main causes of rejections were lack of parallelism of the two barrels and failure of the two barrels to be simultaneously in focus. At first the rejected instruments were returned to the factory for readjustment, but later on the need for these instruments became so great that the rejected instruments were adjusted in the Bureau laboratory and immediately forwarded to the Shipping Board.

Determining Constants of Optical Glass.

All the melts of optical glass made at the Pittsburgh laboratory of the Bureau, about 300 in number, have been submitted in samples to the optical-instruments section for the determination of the refractive indices, dispersions, and transmission factors.

The refractive indices and dispersions were at first determined on a spectrometer. This method involved the expense and delay incident to the making of a small and accurately finished prism of each kind of glass. Subsequently a Pulfrich refractometer, which requires only a small slip of glass about 2 by 10 by 20 millimeters in size, polished on one face and one end, was substituted for the spectrometer and the measurements thereby greatly facilitated. A Martens polarization photometer served for measuring the transmission.

In addition to testing Bureau of Standards melts, measurements of the same sort for a number of other manufacturers of optical glass were made, as also the customary index determinations of other substances.

Tests of Instruments.

Following is a list of tests made by the Optical Instruments Section:

Binoculars.		
For Signal Corps	1,165	
For Naval Ordnance Bureau	13	
For Shipping Board (acceptance tests)	851	
For private individuals	5	
		2,034
Military telescopes.		
Navy sighting telescopes	2	
Gun-sight telescopes	10	
Telescopic sights	2	
Tank sights	12	
Machine-gun panoramic sights	5	
Bore sights	4	
Aiming circles	1	
Range finders	4	
Trench periscopes	6	
Periscopic alidades	3	
Azimuth telescopes	2	
Telescopic clinometers	2	
Sextants	1	
		54
Lens systems.		
Photographic lenses:		
Complete tests	11	
Focal lengths	27	
Radii of curvature	18	
Other lenses:		
Focal lengths	76	
Radii and constants	22	
Centering	72	
		226

Optical glass.

Indices of refraction and dispersion constants	218	
Transmission factors	191	
Indices and dispersions of substances other than glass	27	
		436

Miscellaneous.

Lens test plates, radii of curvature	28	
Refractometers	4	
Parabolic mirrors	4	
Goggles	75	
		111
Total		2,861

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.

Investigations in the general subject of radiometry were greatly interrupted by military work. Research work on the improvement of radiometric devices was carried on with the view of making a practical application in signaling by means of thermal radiations. As a result the investigation of the radiation constants, upon which progress was mentioned in previous reports, has been in abeyance.

A study of the data published by Kahanowicz indicates that if a correction is made for atmospheric absorption the value of the coefficient of total radiation (Stefan-Boltzmann constant) obtained by that experimenter is in close agreement with the value $\delta=5.72\times10^{-12}$ watt, cm^{-2} deg^{-4}, recently obtained in this Bureau.

A further examination was made of the accuracy of the factors used in converting the prismatic spectral-energy curve into the normal-energy distribution. Graphical methods were employed; also computational methods using the first differential of the dispersion formula which best represents the observed refractive indices of fluorite. Owing to incompleteness of the formula, the graphical method is just as accurate as is the method of direct computation. The conclusion arrived at is that the spectral-radiation constant, $C=14353$ micron deg., determined some years ago, remains unchanged.

Among the minor investigations was a determination of the utility of ribbed and hammered glass, as compared with plane glass, in greenhouses. The conclusion arrived at is that, aside from preventing direct sunlight from striking the plants, there appears to be no particular advantage in using a special glass in greenhouses.

Some Optical and Photoelectric Properties of Molybdenite.

A thorough investigation was made of some of the optical and photoelectric properties of the sulphide of molybdenum, molybdenite. The transmissive, reflective, and polarizing properties were determined.

Extensive data were obtained on the spectral photoelectric sensitivity of molybdenite as affected by temperature, intensity of the

142289—19——10

energy stimulus, humidity, etc. This substance is unique in having three well-defined bands of photoelectrical sensitivity. Moreover, the positions of these maxima, when plotted in terms of frequency instead of wave length, are separated by equal intervals. This phenomenon does not appear to have been observed heretofore and will form the basis of a new line of investigation in photoelectric phenomena. An important application of these data was made in signaling by means of infra-red rays, as described in a subsequent paragraph.

Spectral Photoelectric Sensitivity of Silver Sulphide and Other Substances.

In connection with the development of radiometric instruments for signaling by means of invisible radiations, an investigation was made of the spectral photoelectric properties of various substances.

New and important data were obtained on the spectral photoelectric sensitivity of the sulphides of bismuth and silver. The minerals pyrite, cylindrite, jamesonite, and galena did not show photoelectrical sensitivity for the highest spectral-radiation intensities available.

The effect of temperature, of intensity of the exciting light, and of mechanical working upon the photoelectrical sensitivity of silver sulphide was investigated.

At room temperature the photoelectrical sensitivity of crystalline silver sulphide, acanthite, is affected by a polarization phenomenon which disappears at low temperatures. The investigation of these materials has provided new data, the importance and the application of which will no doubt become more apparent as our knowledge of these phenomena is increased. As matters now stand, there is no satisfactory explanation of the cause of photoelectrical sensitivity in substances, and further investigation is highly desirable.

Thermal Radiophonic Signaling Devices.

In the transmission of intelligence by means of invisible thermal radiations radiometry attained one of its greatest triumphs and one of its most far-reaching applications.

The unusually high photoelectrical sensitivity, as well as the quickness of response, of molybdenite, for infra-red rays renders this substance far superior to selenium as a radiophonic signaling device.

Successful field tests were made, using simply a receiver of molybdenite, which was connected through a dry battery to the input side of an audion amplifier. The source of radiation was a small tungsten lamp in an automobile headlight reflector. A rotating sector interrupted the light incident upon the molybdenite and produced a pulsating current, which was amplified, thus producing a loud musical sound in the telephone receiver. Tests were made also using the light of the moon as a source of infra-red radiation. Loud signals could be produced with infra-red lunar radiations having an energy value of only 3×10^{-7} gr. cal. per second.

Ultra-Violet Signaling.

The rotating sectored-wheel device for producing a pulsating current in a photoelectric substance, and hence an audible sound in the telephone receiver of a radiophonic signaling device, is inefficient. Apparatus was devised which utilized all the incident radiation, as well as a long exposure of the receiver, which is not possible with a sectored wheel. The signal was recognized by a change in pitch of the sound in the telephone receiver, which was used with an audion bulb. It was found that the molybdenite receiver is not as efficient as is a photoelectric cell of the gas-ionic type (e. g., the potassium-hydride photoelectric cell), which happens to be sensitive only to the ultra-violet and visible rays, but which appears to be especially adapted to this method of signaling.

Reflecting Power of Stellite and Lacquered Silver.

Stellite has reflective qualities which are promising. The sample examined was more homogeneous and had a higher reflectivity in the visible spectrum than the samples previously reported upon.

In connection with the question of finding a substitute for the glass reflector used in searchlights and other apparatus (which problem was submitted by the War Department), an examination was made of the effect of ultra-violet light upon lacquered silver. It was found that the lacquer undergoes photochemical action which affects the silver and decreases its reflecting power.

Protection of Moving-Picture Film from Heat of Lamp.

In certain work it is desired to stop the movement of the picture film in order to make an examination of the details of a single picture projected upon a screen.

As ordinarily used the moving-picture film is partly protected from injury by the intense infra-red rays from the lamp, because it is exposed to these rays for only an instant. Applying the information obtained in a previous investigation, the intensity of the infra-red rays was greatly reduced by using a dilute solution of cupric chloride which absorbs but little of the visible spectrum, but which is practically opaque to infra-red rays.

Exclusion of Ultra-Violet Light from Buildings.

The problem was presented by the War Department to find a substitute for colored glass to exclude the ultra-violet solar rays from balloon hangars and from other buildings requiring such protection. Tests were made showing that varnishing plain glass with dilute asphaltum varnish is very efficient in absorbing the ultra-violet rays. A better method is to provide a sort of Venetian blind, or louver of wide slats, painted buff to reflect the light into the building.

Information Furnished on Radiometric Subjects—Conferences.

Information was given on various radiometric matters, such as, for example, photoelectric substances; reflectivity data; eye protective glasses; methods of making radiant-power life tests of mercury-vapor lamps; ultra-violet radiations used in life tests of fabrics; substitutes for expensive colored glass in balloon hangars; thermal radiodynamic devices for signaling; radiometric methods of detecting invisible hot objects; demonstration before a special naval board of this Bureau's thermal radiodynamic signaling apparatus.

Publications on Radiometry.

The following publications on radiometry were issued during the past year:

Technologic Paper No. 93 (third edition, revised and enlarged); Glasses for Protecting the Eyes from Injurious Radiations; Scientific Paper No. 325, Spectroradiometric Investigation of the Transmission of Various Substances; Scientific Paper No. 330, The Decrease in Ultra-Violet and Total Radiation with Usage of Quartz-Mercury Vapor Lamps; Scientific Paper No. 338, Some Optical and Photoelectrical Properties of Molybdenite (in press); Technologic Paper No. 128, Effect of Solar Radiation Upon Balloons.

INTERFEROMETRY.

(The light wave used as a fundamental standard of length; variation of this standard length with the medium through which it passes; measurement of very small displacements; general development of interferometry.)

Thermal Expansion of Small Samples.

The expansion of small samples due to temperature changes is most accurately determined by methods that make use of the interference of light waves. A scientific paper describing the apparatus and method with which the expansion of a single pin, 10 millimeters long and 5 square millimeters in cross section, can be determined is ready for publication. The description of the apparatus and method for determining the expansion of three different samples simultaneously was published in the Journal of the Washington Academy of Science, May 19, 1919. Suitable temperature-control apparatus has been installed, so that expansion determination can be made with the temperature range —190° to 1,000° C. During the past year the thermal expansions of 85 samples of optical glass were measured over the temperature range 20 to 650° C. Several tests were made for different glass manufacturers. Other materials, such as invar, steels from which precision gauges are made, human teeth, and dental porcelains and amalgams, were investigated.

Dimensional Changes of Dental Materials.

In connection with the Bureau's investigation of dental material, which was undertaken at the request of the Surgeon General's office, interference methods were employed to make measurements of dimensional changes of the materials. Changes of dimension usually takes place in porcelain and amalgam used in filling teeth for some time after they are made up. Measurements of these changes, commencing a few minutes after the material was prepared and extending over a period of from one to four days, were made on 90 samples. In order to determine the effect of temperature changes on fillings, the thermal expansions of teeth and different kinds of materials were investigated. It was found that the expansivity of the amalgams was about four times that of the teeth, while for porcelain it was about the same. The results of this investigation are ready for publication.

Standardization of Precision Gauges.

Precision end gauges, which are steel blocks with two opposite faces plane, parallel, and a specified distance apart, are used as master gauges for precise mechanical work. These gauges are made so nearly perfect that it is impossible to determine their errors with any contact micrometric apparatus. Interference apparatus and methods have therefore been employed in the calibration of these gauges. During the past year several sets of gauges were calibrated relative to the standard light waves and a large number of other gauges were compared with the secondary standards. Seven thousand six hundred gauges manufactured at the Bureau and 3,500 from manufacturing companies were tested. Change in dimension with age and change in thermal expansivity, with the composition and heat treatment of the steel used, were found to be important factors in the reliability of precision gauges.

DISPERSOIDS.

(Investigation of the physical properties of dispersoids, such as smokes, water supplies, biological fluids, gelatin films, 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.)

Properties of Smoke.

The word "smoke" denotes the products of combustion forming a visible cloud of small particles. These may be either solid, as the carbon particles from a sooty flame, or liquid, as the vegetable-oil particles in tobacco smoke. Smokes are of military importance for screening purposes, and the attention of the French Commission, during their visit to the Bureau, was called to its great utility at the front.

During the war the Bureau was asked to cooperate with the Chemical Warfare Service in investigating the properties of toxic smokes. To do this most quickly and thoroughly the Bureau specialist worked with the research division of the Chemical Warfare Service. For the work of the gas-mask research section it was necessary to design a sensitive photometer for measuring the smokes which could be produced in this country. Two of these instruments, built by the American Standard Motion Picture Co., were completed when the armistice was signed. Some parts of the joint investigations with the dispersoid section of the service were published in the Journal of the American Chemical Society, volume 41, pages 312–329.

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 (18,436) of chemical tests made in the chemical laboratories during the year slightly exceeded that of the preceding year. Distributed by types of materials, they were as follows: Ferrous metals (irons and steels), 1,177; nonferrous metals, alloys, and coated metals, 960; cement and cement materials, 8,091; bituminous products (including creosotes, etc.), 1,129; varnish materials (including shellacs), 839; paint materials, 1,016; lubricants, 557; soaps, nondrying oils, and metal polishes, 674; inks and related office supplies, 673; balloon fabrics, 840; rubber, 906; leather, 421; textiles, 745; miscellaneous, 408.

The tests were made for very many Government bureaus and establishments and for States, municipalities, and private parties, as follows: Agriculture, 102; Commerce, 10,057; Navy, 737; Post Office, 474; Treasury, 525; War, 4,409; Panama Canal, 1,171; General Supply Committee of the District of Columbia, 533; U. S. Shipping

Board, 148; other Federal institutions, commissions, and committees, 220; State, municipal, and other institutions, 34; private parties, 26.

Chemical Publications.

The following papers emanating wholly or in part frem the chemistry division were published during the year or are nearly ready for publication:

Zinc-Cyanide Plating Solutions, published in Monthly Review American Electroplaters' Society, volume 5, Nos. 11 and 12, and volume 6, No. 4, 1918.

Military Applications of Electroplaitng, published in Metal Industry, volume 16, page 498, 1918.

Notes on Black-Nickel Plating Solutions, to appear in Monthly Review American Electroplaters' Society.

Operation of Fluoborate Lead-Plating Baths, to appear in Review American Electroplaters' Society.

Lead Plating from Fluoborate Solutions, to appear in Transactions American Electrochemical Society.

Factors Governing the Structure of Electrodeposited Metals, to appear in Transactions American Electrochemical Society.

Report on Ladle Test Ingot Investigations, to be published as an appendix to the report of committee A-1, American Society for Testing Materials, 1919.

Electrolytic Resistance Method for Determining Carbon in Steel, to be published in Journal of Industrial and Engineering Chemistry.

Technologic Paper No. 118, Critical Study of the Ledebur Method for Determining Oxygen in Iron and Steel.

Technologic Paper No. 126, A Study of the Goutal Method for Determining Carbon Monoxide and Carbon Dioxide in Steels.

Scientific Paper No. 346, Oxygen Content by the Ledebur Method of Acid Bessemer Steels Deoxidized in Various Ways.

Scientific Paper No. 350, Equilibrium Conditions in the System Iron Oxide, Carbon, and Hydrogen in Relation to the Ledebur Method for Determining Oxygen in Steel.

Technologic Paper No. —, Investigations at the Bureau of Standards on Gases in Steel and on Deoxidation of Steel, also to appear in Bulletin Institute of Mining Engineers.

The Generation of Hydrogen from Ferrosilicon and a Solntion of Sodium Hydroxide (Methods of Study), to appear in Journal of Industrial and Chemical Engineering.

The Generation of Hydrogen from Ferrosilicon and Sodium Hydroxide (Details of Experiments and Recommendations), published in Fourth Annual Report National Advisory Committee for Aeronautics.

The Use of Lime in the Generation of Hydrogen from Ferrosilicon and Sodium Hydroxide, published in Fourth Annual Report National Advisory Committee for Aeronautics.

The Effect of the Presence of Sodium Carbonate on the Generation of Hydrogen from Ferrosilicon and Sodium Hydroxide, published in Fourth Annual Report National Advisory Committee for Aeronautics.

The Use of Ultra-Violet Light for Testing Balloon Fabrics, published in Fourth Annual Report National Advisory Committee for Aeronautics.

Characteristic Exposure Tests of Balloon Fabrics, published in Fourth Annual Report National Advisory Committee for Aeronautics.

The Testing of Hydrogen for Balloon Fabrics, published in Fourth Annual Report National Advisory Committee for Aeronautics.

Cemented Seams and Rubber Cements with Reference to Balloon Construction, published in Rubber Age and Tire News, volume 4, page 421, 1919.

Balloon Fabrics and their Testing, published in Textile World Journal, volume 55, page 1047, 1919.

Scientific Paper No. —, Efflux of Gases Through Small Orifices.

Circular No. 81, Bibliography of Helium, also in Journal Industrial and Engineering Chemistry, volume 11, page 682, 1919.

Technologic Paper No. 131, Application of the Gas Interferometer to Gas Analysis.

Preparation and Testing of Pure Hydrogen, to appear in Journal of Industrial and Engineering Chemistry.

A Method for Determining the Permeabiliy of Balloon Fabrics, to appear in Journal of Industrial and Engineering Chemistry.

The Significance of Oxygen in Balloon Gas, to appear in Aviation and Aeronautical Engineering.

Technologic Paper No. —, New Forms of Combustion Apparatus for Use in Gas Analysis, to appear also in Journal of Industrial and Engineering Chemistry.

Technologic Paper No. 128, Effect of Solar Radiation on Balloon Fabrics.

Automatic Methods of Gas Analysis Depending Upon Thermal Conductivity, in preparation.

The Permeability of Rubber to Various Gases, in preparation.

Comparative Tests of Palau and Rhotanium Ware as Substitutes for Platinum Laboratory Utensils, published in Journal Industrial and Engineering Chemistry, volume 11, page 570, 1919.

Technologic Paper No. 136, the Determination of Free Carbon in Rubber Goods, also in Journal of Industrial and Engineering Chemistry, volume 11, page 33, 1919.

Mercerization of Cotton Yarns, to appear in Textile World Journal.

Analyses of Different Tannages of Strap, Harness, and Side Leathers, to appear in Journal American Leather Chemists' Association.

Technologic Paper No. 138, Effect of Glucose and Salts on the Wearing Quality of Sole Leather.

Technologic Paper No. 138, Wear Resistance of Sole Leather.

Technologic Paper No. 145, The Direct Determination of Rubber by the Nitrosite Method.

Metallic Coatings for Rustproofing Iron and Steel, published in Chemical and Metallurgical Engineering, volume 20, page 458, 1919.

Technologic Paper No. 140, Constant Temperature Still-Head for Light-Oil Fractionation, to appear also in Journal Industrial and Engineering Chemistry.

Circular No. 62 (revised), Specifications for and Methods of Testing Soap.

Circular No. 82, Specification for Linseed Oil—Raw, Boiled, and Refined.

Technologic Paper No. 132, The Mechanical Properties and Resistance to Corrosion of Light Alloys of Aluminum and Magnesium with Copper, with Nickel, and with Manganese.

Circular No. 80, Protective Metallic Coatings for the Rustproofing of Iron and Steel.

PHYSICAL CHEMISTRY.

(Preparation and purification of materials required in physical measurements of precision—for example, refrigeration materials, calorimetric samples, materials for standard cells, and for density determinations; determination of certain physical constants and development of methods for their exact determination.)

Refrigeration Materials and Problems.

In extension of the work of the previous year additional samples of pure ammonia were prepared for the making of vapor-pressure determinations in the heat division. The presence of extremely minute quantities of permanent gas affects these measurements considerably, particularly the ease with which equilibrium is attained. The method of testing for small quantities of permanent gas has proved very useful in this work and in that of the density of the gas (or weight of a normal liter) as a criterion of purity. Little work on ammonia remains to be done, and a publication is in preparation on the purification and physical properties of ammonia which will be quite extensive in scope.

The plant installed for a study of gas formation in compression systems of refrigeration has been in operation for several months, and a report upon the subject is contemplated for the next meeting of the American Society of Refrigerating Engineers.

Purification of Materials for Special Purposes.

Standard samples.—Considerable work has been done on the renewal of benzoic acid and naphthalene as standards for calorimetry. The former, of satisfactory quality, was unobtainable during the war, but now rather large quantities of both raw materials are available from which to prepare the pure standards from time to time. Facilities have been lacking heretofore for the purification of quantities large enough to last for more than a few months; but the installation of new and larger equipment will permit of preparing stock to last for at least two years.

Mercury.—Mercury purification is now on practically a routine basis. Aside from supplying the needs of the Bureau, material has been furnished to the Geological Survey, the Weather Bureau, and the Magnetic Laboratory of the Carnegie Institution. Considerable work was done on methods of testing mercury as to purity, particularly by the measurement of its electromotive force.

Methane.—Supplementing work of the previous year, several additional samples of pure methane were prepared for the determination of its thermal properties by the heat division. The preparation of this gas requires a very elaborate arrangement of apparatus and the continuous attendance of operatives for as much as 48 hours at a time.

Methyl alcohol.—Considerable attention was given to the purification of methyl alcohol for use in determinations of density by the division of weights and measures. A series of samples from various sources was prepared and tested for purity by use of the critical solution-temperature method.

Critical Solution Temperature Work.

Experimental work is being conducted on the quantitative application of the critical solution-temperature phenomenon (1) as a criterion of the purity of chemical substances; (2) to the determination of the composition and constituents of petroleum products, especially gasoline; (3) to the determination of the quantity of water absorbed by gasoline, transformer oils, and other products which dissolve small quantities of water; (4) the miscibility relations of the alcohols and hydrocarbon mixtures, such as kerosene, as bearing on the utilization of the higher boiling hydrocarbons as internal-combustion motor fuels.

The fundamental data necessary to the application of this method to the problems listed above are the equilibrium relations in the various binary systems, showing two liquid layer phenomena with an upper critical solution temperature (the temperature above which two liquid layers can not exist). Methyl alcohol, ethyl alcohol, aniline, nitrobenzene, and formic acid are substances which show these phenomena with certain compounds and types of compounds forming the constituents of the lower-boiling petroleum products. The change in the value of the critical solution temperature of these substances with various types of hydrocarbons and with various members of the same series promises to contribute materially to our knowledge of the constituents of gasolines and the analytical methods which can be applied to this very complicated problem. The data obtained from these solubility curves are also available for purity tests of different samples of the various substances involved. Methyl alcohol used in this work has been checked as to purity with pure samples of carbon disulfide. The equilibrium relations between these two substances have been determined, as well as those in the system ethyl alcohol—carbon disulfide. Several samples of commercial aniline have been tested and purified and used in the examination of gasolines. In addition to the characterization of types of gasolines by this phenomenon, it is found that the great effect of water on systems of this type can be utilized in determining small quantities of water and the solubility of water in liquids dissolving water sparingly. Before applications of this kind can be made it is necessary to determine the effect of known quantities of water added to the system. The work is progressing mainly toward the acquisition of the fundamental data necessary preliminary to the practical application of the method to more specialized engineering or technical problems.

Determination of Physical Constants.—It is aimed to provide equipment and permanent arrangements for the precise determination of some of the more commonly used physical constants, particularly those useful to organic chemists in the identification of compounds. Thus far most attention has been paid to freezing-point determinations of mixtures as well as single substances; for instance, of various samples of motor fuels. It is expected to extend the work to the determination of boiling points, refractive indices, and densities.

Glass-to-Metal Joint.—A glass-to-metal joint has been devised and used very successfully in work with gases under high pressure. The joint is tight under a complete vacuum and is resistant to very high pressures, facts which make it very useful in laboratory work in physical chemistry.

Atlas of Heterogeneous Equilibria.

In the report for 1916 reference was made to a proposed atlas of heterogeneous equilibria. Work on this compilation has progressed satisfactorily, and the information so far accumulated has been very useful in the work of the chemistry division and in the correspondence referred to it.

ELECTROCHEMISTRY.

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

Electroplating.

During the first half of the fiscal year the section was actively engaged in problems connected with the electroplating of military supplies. Such problems were very numerous and varied and involved a great amount of travel and conference with manufacturers and military officials. While in most cases the military applications of plating were, or appeared to be, incidental, the prompt delivery of materials and the durability of the products during storage and transportation or in field use, were often determined by the success or failure of the plating operations. The need for definite information was emphasized by the almost absolute lack of commercial standards or specifications, in consequence of which fact delays and confusion were not unusual. Through conferences with manufacturers and military officials this Bureau was able to suggest tentative specifications which were mutually satisfactory. In general, in such specifications the purpose was to give as much latitude to the manufacturers as would permit satisfactory products, and also to unify and systematize, so far as possible, the requirements of different military branches for similar products or for materials subject to similar use and exposure.

The research work carried on at the Bureau was devoted principally to meeting immediate military needs. Consequently it was not possible to conduct any exhaustive or detailed investigations. Nevertheless, much information of value to the plating industry was obtained, and an acquaintance with platers and manufacturers and their needs was secured which will, it is believed, be of great value in further research in this field.

The principal military applications of electroplating which were investigated at the Bureau were as follows:

Lead Plating.—This had very little commercial application prior to June, 1918, at which time a demand arose for lead coatings in connection with gas shells. Within a few months a considerable number of plants were prepared to carry out this operation, using either fluosilicate or fluoborate solutions. In view of certain advantages possessed by the latter solutions, they were investigated by this Bureau, and working directions were furnished to manufacturers. Other applications of lead plating were the bringing up to weight of underweight shells, of which many thousands were thus salvaged, and, to a less extent, the lining of chemical equipment. Possible commercial applications of lead plating are being investigated.

Black Nickel Plating.—This operation was very extensively used to produce a black finish upon military equipment. The formulas in commercial use were very involved and frequently unsatisfactory. As a result of investigations at the Bureau, simple satisfactory formulas were recommended.

Zinc Plating.—In view of the fact that zinc is the only metal that furnishes intrinsic protection against corrosion of steel, zinc coatings have proved very valuable. Of the three methods of producing satisfactory zinc coatings—viz, hot dipping, sherardizing, and zinc plating (electrogalvanizing)—the latter is frequently most convenient, especially for small parts, or those which are threaded or dimensioned or those having previous heat treatment and which might be injured by reheating. It was found that entirely satisfactory zinc plating can be conducted in either cyanide or sulphate solutions. Results of the investigation of the cyanide solutions have been published, and the work on sulphate solutions is still in progress.

There were many minor military problems and applications of electroplating submitted for consideration, all of which showed the need in this industry for better definition of methods of plating and of testing plated products. Throughout in these investigations the Bureau has had the active support and cooperation of the American Electroplaters' Society, three of whose members, at considerable financial sacrifice, devoted their entire time to this work. With the cessation of hostilities and the consequent reduction in military demands and financial support it was no longer possible to retain any considerable staff upon electroplating problems. In view, however, of the importance and far-reaching applications of electrodeposition, arrangements have been made to devote a limited sum from the industrial research fund to these investigations during the fiscal year 1919–20. In addition, it is hoped that some financial support may be furnished by manufacturers interested in plating.

While these investigations will be conducted with a view to securing information of industrial value and to publishing it in a form useful to practical platers, experience has shown that permanent and far-reaching progress in this field must involve fundamental studies of electrodeposition, requiring the services of persons especially qualified in physical and analytical chemistry and metallography, and at least one person thoroughly acquainted with the present methods and needs of the electroplating industry. The possible scope of work in this field may be judged by the many kinds of electroplating which find application in the most varied industries. Thus, in addition to the lead, zinc, and black nickel plating previously referred to, nickel, silver, brass, copper, gold, and tin plating are all extensively employed. Progress in this field will involve a considerable annual expenditure, which, however, is fully warranted by the importance of electrodeposition in its varied applications.

METALLURGICAL CHEMISTRY.

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

The work done by the chemistry division, in connection with metallurgy, is reported under "Metallurgy" (p. 258).

GAS CHEMISTRY.

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

The two most important and extended lines of work carried on by the gas section during the past year were (1) the testing and investigation of the properties of balloon fabrics and (2) the development of a method of automatic gas analysis, the possibilities of which have not heretofore been appreciated. The other investigations carried out by the section, in most of which the Bureau served the military and naval departments in the capacity of a consulting chemical engineer, were of too varied a nature to permit classification. Thirty-two reports and publications were made or are in preparation.

Balloon Fabrics.

The testing of balloon fabrics for permeability and lasting qualities has continued along the lines so well established during the preceding year. The volume of work has been very large, not only during the war, but since the signing of the armistice, because of the extensive experimental program of the Navy. The total number of fabrics tested during the year was 710, 1,520 individual tests of various kinds being involved.

In addition to this regular testing work, investigations were made along the following lines:

1. The permeability of various materials to helium. An investigation to determine the suitability of the present fabrics for making helium balloons and, if possible, to develop improved fabrics for the purpose. The properties of ordinary fabrics have been well

ascertained, but no improved fabric for use with helium has resulted.

2. The permeability of rubber to various gases. An investigation made to determine not only the usefulness of rubber as a container for various gases, but also to shed light on the mechanism of permeability.

3. The relation of the thickness of rubber films to permeability.

4. The relation to permeability of the partial pressure of a gas and the nature of its diluent.

5. The relation of temperature to the permeability of rubber films. The principal significance of (4) and (5) is in connection with testing methods.

6. The effect of solar radiation on balloons. This investigation included the heating of the fabric and the temperatures in various parts of the balloon, convection losses from balloons in flight, the effect of radiation on the lasting qualities of the fabric, the protection of the fabric from injurious effects, and the effect of pigments in fabrics upon the changes of balloon temperature and the visibility of balloons.

7. The microscopic examination of fabrics. This work, carried out upon transverse sections, proved of great assistance in connection with a number of problems, but particularly in connection with cements and seams.

8. Acidity tests of fabric. It was found that a part of the deterioration of the fabrics in service was caused by sulphuric acid formed by the oxidation of the sulphur used in compounding the rubber.

9. The relation of permeability to the thread count of the fabric. Shortly before the signing of the armistice this problem assumed considerable importance, because the production of balloon fabrics at that time appeared to be limited by the possible output of the machinery available for the manufacture of the very fine fabrics used for the purpose.

10. The deterioration of fabrics under tension. This investigation was intended to supply information relative to the abnormally short life of dirigibles in service. No conclusive results were obtained.

11. A comparison of the American and Italian methods of making life tests of fabrics. This investigation is still continuing. Thus far there is no indication that the Italian method (exposure to the weather with hydrogen on one side) is superior to the American methods.

12. A comparison of the English and American methods for making permeability tests.

13. A study of exposure tests of fabrics at Washington and Pensacola. A study of the significance of various meteorological conditions in the deterioration of the fabrics.

14. The effect upon balloon fabrics of impurities in hydrogen and of contact with metal fastenings. These tests showed what metals could be safely used in balloon construction, and indicated that the elimination of the last traces of gaseous impurities from hydrogen is unnecessary.

15. A study of balloon seams and rubber cements for making seams. This work gave some very valuable information regarding the construction and causes of failure of balloon seams.

16. The development of two more rapid methods of making routine permeability tests which should be of considerable importance in case sudden rapid expansion of balloon production is again required.

17. The determination and partial elimination of a source of error in making permeability tests due to the passage of gas between the layers of fabric.

The above investigations were all carried out in the closest cooperation with the Army, the Navy, and the manufacturers; and since none of these parties had any adequate facilities or personnel for the study of such problems, the work done by the bureau may be regarded as of fundamental importance. Many reports and publications on these subjects have been made or are in preparation.

Automatic Gas-Analysis Apparatus.

Without doubt, the work of most importance to American industry accomplished by the section during the year was the development of some simple and extremely sensitive apparatus and methods for the automatic analysis of gases. This work was undertaken at the request of the Nitrate Division of the Ordnance Department in connection with the analysis of the complex gas mixtures employed in the synthetic manufacture of ammonia. Apparatus was designed and the measuring instruments had been constructed and calibrated for the chemical control of the big plant at Sheffield, Ala., when the armistice was signed and work at that plant ceased. A smaller apparatus has, however, been constructed for the use of the experimental plant at Arlington and is now in use at that place.

Apparatus was also constructed for recording the percentage of helium in the preparation of that gas for balloon purposes and has been installed in the fractionating plant at Petrolia, Tex. This apparatus, after installation, was also adapted for recording the composition of the raw gas entering the plant. Similar apparatus for making and recording 12 continuous analyses simultaneously is now under construction for use in the big helium plant at Fort Worth.

This type of apparatus has been tried out successfully for so many purposes that the following list of the determinations possible by this method seems justified: (1) Practically any binary mixture of which the constituents are known. (2) Practically any easily absorbable constituent of a gas mixture containing no other constituent which reacts with the reagent used. (3) Any single combustible gas in air or oxygen. (4) Oxygen, hydrogen, nitrogen, carbon monoxide, and carbon dioxide in mixtures containing these gases only. (5) Total carbon or total carbon, except carbon dioxide, in most gas mixtures of industrial importance. (6) Oxygen required to burn any ordinary reducing gas mixture or oxygen required to burn all the reducing constituents except hydrogen. (7) Hydrogen or helium in any ordinary mixture. Many other combinations are, of course, possible. A single electrical measuring instrument or recorder can be easily adjusted to read any one of several such analyses on the same decimal scale or to read directly a linear function of the composition, such, for instance, as the permeability of fabrics in suitable units. The apparatus can also be made to automatically control various mechanisms. The analysis of flue gases, mine air, blast-furnance gases, and many industrial gases can probably be put on a recording basis with apparatus much superior to any now in use for similar purposes.

One of the foremost instrument manufacturers in the country is to undertake the manufacture of this apparatus in the near future.

Miscellaneous Problems.

1. A determination was made of the limits of inflammability of mixtures of hydrogen and helium, particularly when issuing from orifices of various sizes. A considerable amount of work was also done on the analysis of helium mixtures in connection with the numerous problems involving that gas.

2. The bibliography of helium literature was revised.

3. A technical report was rendered on the practicability of producing ammonia as a by-product in the separation of helium from natural gas, according to a method proposed by the engineering laboratory of the United States Naval Academy.

4. Analyses of the exhaust gases from airplane engines were made throughout most of the year for the gas-engine section.

5. A considerable amount of work was done upon the selective combustion of carbon monoxide in gas analysis, and upon the determination of carbon dioxide, of water, and of ammonia in very small amounts in gases by electrolytic conductivity methods. Some of the methods studied give promise of usefulness when there is opportunity to develop them further.

6. Tests were made at Langley Field to determine the performance, as to yield and purity, of the large hydrogen plant installed there. Acceptance of the plant and the compensation paid the contractor was based on these tests.

7. A considerable amount of time was devoted to cooperative tests with the Bureau of Aircraft Production upon the ignition of balloons by incendiary bullets.

8. A number of useful pieces of apparatus and methods of laboratory work were developed. The most important of these is a form of bridge for measuring directly the difference of conductivity of two electrolytes.

9. A determination of the temperature of inflammability of organic material in contact with sodium nitrate was made for the Railroad Administration. This problem arose in connection with the storage of this material in warehouses and docks.

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.

Owing to the limited force, abnormal conditions, and the miscellaneous tests made for the Military Establishments, little progress has been made in the study of the methods of analysis of the so-called "analyzed reagents." Most of the work has consisted in the testing of reagents purchased for the use of the laboratories of this Bureau. This work indicates that there is room for improvement in most, if not all, of the reagents tested. This study having been taken up in cooperation with the American Chemical Society and the manufacturers, a report has been submitted to the chairman of the committee on analyzed reagents of the American Chemical Society, and manufacturers advised of the discrepancies between the printed labels and the actual findings. A synopsis of this report was published in the Proceedings of the American Chemical Society, 1919. As the quality of chemical reagents is of direct interest to all scientific and industrial laboratories, and indirectly affects all users of the products of the industries, means should be provided for prosecuting this work in a systematic way.

Platinum.

The research upon the chemical and physical properties of the platinum metals has been continued. The analytical methods given in the literature have been studied and the information so obtained applied in the examination of various samples submitted for test. The preliminary purification of platinum, palladium, and iridium has been completed, and the study of the physical properties of the pure metals will soon be taken up. Analyses were made of platinum gauzes for use as catalysts in the oxidation of ammonia by the Nitrate Division of the Ordnance Bureau. Owing to the price of iridium and the necessity for conservation, the Bureau of Aircraft Production had prepared platinum-iridium alloys containing varying percentages of iridium to be used in the manufacture of magneto contact points. Service tests and chemical analyses were made by this Bureau. The analyses showed that only about 50 per cent of the iridium content claimed was found in each case. The standard platinum-iridium alloys in general use contain 15 to 20 per cent of iridium. This work was discontinued on the signing of the armistice.

Negative tests of reputed platinum ores were made at the request of Government offices, analyses of various platinum metals were made for the United States assay office, and miscellaneous tests made and reports rendered for military branches of the Government.

Through the cooperation of the nitrate division of the Ordnance Department, United States Army, the Bureau has received for use in research 72 ounces of platinum residues from the United States assay office. Unfortunately, the important metal rhodium was found to be almost lacking in these residues.

The United States assay office, continuing its cooperation of the previous year, has made for the Bureau many vessels and articles of platinum and some of gold.

Platinum Substitutes.

The shortage of platinum shortly before and during the war aroused the interest both of commercial organizations and the public in general. Quite a number of "platinum substitutes" were developed and samples submitted to this Bureau for test. Most of this work was done for the platinum section of the War Industries Board. The substitutes proposed for platinum were of two kinds; those composed of base metals, and alloys of the noble metals. No base metal substitute was submitted which approached platinum in general usefulness or was suitable for laboratory operations. Two base metal alloys were examined which were found suitable for the purposes for which they were designed. One was an alloy very resistant to nitric acid and submitted by the nitrate division; the other could be used for electrical contact points under a limited range of conditions. In one case steps were taken to suppress wildly extravagant advertising. Of the noble-metal alloys two were examined, known as "palau" and "rhotanium." Both are alloys of gold with relatively small amounts of palladium. These were tested in conjunction with the metallurgical division and were found suitable substitutes for platinum in numerous operations in the chemical laboratory.

Miscellaneous Tests.

Various miscellaneous tests were made for military and other offices, among which were (*a*) enamel ware, (*b*) lead, barium, and borosilicate optical glasses, (*c*) aluminum sulphate (inspection and sampling of a 500.000-ton lot for the Panama Canal).

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, steel alloys, ores, chemicals, etc.)

Standard Analyzed Samples.

The number of standard samples called for during the fiscal year 1919 was 4,944, an increase of 108 over the previous year. The distribution was as follows: Irons and steels, 3,627; brass, 93; ores, 307; sodium oxalate, 325; naphthalene, 87; benzoic acid, 108; sucrose, 95; dextrose, 16; metals for melting points, 154; cement for testing sieves, 132.

The greatly increased calls for standard samples during the war left the Bureau with a much-depleted stock. This necessitated a curtailment of the distribution. In this connection it should be pointed out that the money value of the samples issued was more than twice the total appropriation for the work, namely, $4,000. Even with the fund available for the fiscal year 1919—namely, $5,000—it will be impossible to keep up the stock of samples already listed. The preparation of samples has been confined entirely to the renewal of the stocks of those listed.

The private enterprise in England mentioned in the last annual report requested the Bureau to cooperate in the analysis of a standard sample of chrome-vanadium steel, and to secure the cooperation of two outside analysts.

Determination of Tungsten, Molybdenum, Zirconium, and Uranium in Ores and Metallurgical Products.

Continuing the cooperative work referred to in the last annual report, methods have been worked out for the determination of tungsten, molybdenum, zirconium, and uranium in metallurgical products and in ores of the three first-named metals.

Miscellaneous Researches.

In addition to the above researches a number of others have been carried out, which served to clear up obscure points in analysis, namely, precipitation of zirconium as phosphate, volatility of phosphoric acid upon fuming with sulphuric acid and fusion with alkali pyrosulphate, determination of small amounts of aluminum in presence of large amounts of zinc, determination of small amounts of calcium in presence of large amounts of magnesium, study of temperatures obtainable with the ordinary types of laboratory burners, behavior of manganese and vanadium in the precipitation of iron and aluminum with ammonium hydroxide, according to the procedure of Blum.

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

(Chemical analysis and investigations of oils, rubber, paper, textiles, ink, glue, airplane dopes, etc., with special reference to meeting particular requirements.)

Airplane Dopes.

After the Signal Corps established its own laboratory in Pittsburgh, Pa., work was continued for the Bureau of Construction and Repair, Navy Department, not only until the signing of the armistice, but up to the present time. Numerous trips were made to manufactories of dopes and of airplanes, as well as to aviation fields, in the interest of the Navy.

Early in this calendar year the Department of Military Aeronautics, which had taken over the aviation program of the Signal Corps, found it advisable to return to the Bureau for assistance in the preparation of a lengthy report on foreign practice in doping and related matters. Part of the statements made by military observers abroad were of such doubtful reliability and so open to question that this Bureau was asked to test many of them by laboratory experiments.

Chemistry of Leather.

Full details of the Bureau's work on leather, including that of the chemistry division, are given in the report entitled "Leather" (p. 224).

Chemistry of Rubber.

Full details of the Bureau's work on rubber, including that of the chemistry division, are given in the report on rubber (p. 220).

Chemistry of Textiles and Commercial Dyes.

Full details of the Bureau's work on textiles and commercial dyes, including that of the chemistry division, are given in the report of the textile section of Division VII (p. 227).

Pure Dyes.

A great deal of time was devoted to the preparation of about 30 carefully made and purified dyes. This was done in connection with the projected development of a comprehensive method for the identification and analysis of dyes by spectroscopic measurements. Commercial dyes can not be used to obtain the fundamental data, because they are rarely single, pure substances, but generally contain colored organic impurities. Different salts of metals are also frequently admixed. It is obviously impossible to determine the character and intensity of color of the dye in such a mixture.

Camouflage.

A statement of the work on dyed fabrics and screens for camouflage and secret signals appears in the report of Division IV.

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Photographic Sensitizers.

One of the most valuable dyestuffs for sensitizing photographic plates to certain portions of the spectrum is dicyanin. This is a German product. Very little has been published about its chemical nature or the method of preparing it, and that little is probably misleading or lacking in some important detail. Attempts to produce dicyanin led to the discovery of a dye which is in some respects superior to it.

Chemistry of Inks.

Writing and Copying Inks.—A great many writing and copying inks were tested to assist the General Supply Committee and the Post Office Department in awarding contracts, and also to check deliveries made by contractors. There was evident an increasing tendency to manufacture inks from Prussian blue. This color is very permanent under some conditions, but has the disadvantages of not turning black and of being readily removable by a simple chemical treatment.

The most suitable inks for permanent writing contain iron gallotannate. On the paper this soon oxidizes to an intense black, although the writing is at first very pale. To get around this, a suitable dye is always used. For a considerable time after the supply of German dyes was exhausted American ink manufacturers had great difficulty in getting suitable dyes. The Bureau learned where satisfactory colors were made, and was thus able to help more than one ink manufacturers to improve his product.

Ink Tablets and Powders.—For many years various brands of tablets and powders for making writing ink by simply dissolving them in water have been on the market. They are more convenient than ink in liquid form, because they occupy so little space in shipment and storage; they can not freeze and break the bottles; they keep indefinitely; and they can be sent safely by mail. For these and other reasons the Army sent many thousands of tablets and powders abroad. The same reasons appeal to the Post Office Department, which supplies post offices throughout the country from Washington.

Until recently these powders and tablets have been made of "aniline," or, more correctly, synthetic, dyes. Such inks can not have sufficient permanence for record inks, and for that reason the Bureau has consistently refused to recommend them for use by the Government departments.

Red and other colored inks are necessarily made from dyes. It is immaterial whether these are put on the market in solid or liquid form.

Within the past year a few brands of gallotannate of iron tablets have been tested by the Bureau. Some of these were of a fairly satisfactory quality, but others were not only turbid when freshly dissolved, but the ink so prepared deposited large quantities of a thick, gummy sediment in a few days. Properly made liquid inks give very little sediment, because enough hydrochloric or other mineral acid is added to keep the iron compounds in solution. These acids, being liquids, can not be used in powders and tablets. The Bureau found that solid organic acids such as oxalic, or acid salts such as sodium bisulphate, can be used with success. This information was passed on to manufacturers of this type of ink.

Concentrated Inks.—Possibly owing to the difficulty of making suitable ink powders and tablets, some manufacturers have recently placed concentrated inks on the market. If properly made and not too greatly diluted, there is no reason why they should not be used for permanent records.

Indelible Inks.—A considerable quantity of indelible ink was used by various branches of the military organization for marking blankets, bales, etc. A great variety of materials was used in making these inks. By laboratory tests and by washing in a commercial laundry it was learned that a dye of good quality, dissolved in cresol, made the most permanent ink.

Miscellaneous Inks.—Among other classes of ink tested were the following: Stamping, drawing, and stenciling inks, and those to be used with canceling machines, duplicators, and hektographs.

Typewriter Ribbons.—Many ribbons for use on typewriters, as well as similar ribbons for time recorders, adding and computing machines, etc., were examined and tested. The quality of the fabric, the amount of ink, and the permanence of the writing were all considered in making the tests.

Carbon Papers.—Comparatively few carbon papers were received for test. The weight and quality of the paper, and the nature and amount of the coating were determined.

Printing Inks.

The Bureau made only a few analyses of printing inks, but much time was spent in devising a method for determining the properties known to printers as "tack," "length," or "shortness," and "carrying power" of vehicles, the oil absorption of pigments, and the rate of setting vehicles and inks. By this method the results are expressed numerically and duplicate determinations give closely concordant figures.

Some progress has been made in correlating the data obtained in the laboratory with the behavior of the inks on the press, but many phases of the subject remaining to be investigated before the work can be regarded as complete.

Printers' Rollers.

Printers' rollers are made of glue, water, and molasses or glycerol. A difficulty with rollers made with cane molasses is that they can not be melted and recast after they have become hardened in service. The Bureau devised and patented a method of using specially prepared beet molasses instead of cane molasses. The behavior of these rollers in service shows that they can be used much longer than the other without hardening. They can also be remelted.

The patent (United States 1,284,172), issued November 5, 1918, was dedicated to the public.

Glue, Mucilage, Paste.

About 100 samples of glue, mucilage, and paste were tested for the Government.

Miscellaneous.

Among the minor items in which the section was interested were: Paper boxes for shoe polish, safety matches, linoleum pastes; examining mangrove roots for tannin and dyestuffs; examining morinda roots for dyestuffs; preparing inks for recording instruments and for use in connection with the etching of graduated glassware; preparation of a liquid for use on mimeograph stencils; bleaching freshwater pearl buttons, etc.

Examination of Materials for the Steamboat-Inspection Service.

The Steamboat-Inspection Service depends upon the Bureau not only for the testing of goods that may possibly be prohibited on passenger steamers but also for options as to the propriety of carrying chemicals and other similar substances.

The Bureau agrees with the service that the existing Federal law (Sec. 4472, R. S.), which was passed 45 or more years ago and which has been amended several times, is self-contradictory and hampering to foreign trade. The Steamboat-Inspection Service and the Bureau of Standards independently made recommendations to the Secretary of Commerce that steps be taken to have this old statute replaced by one abreast of the times. Their suggested outlines for a new law were surprisingly alike.

METALS, CEMENT, AND BITUMINOUS MATERIALS.

(Chemical analysis of metals, including iron, steel, nonferrous metals, alloys, such as brass, type metal, and solder; coated metals, such as tin plate and galvanized metals; 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 metals and alloys, much attention has been given to trying out and improving methods of chemical testing. Many tests were made for the purpose of supplying information to other divisions of the Bureau to aid in determining the most suitable materials for various military needs and to explain causes of failure. A number of special metals and alloys were analyzed.

An exposure test to determine the relative resistance to corrosion of uncoated sheet iron and steel was made in cooperation with the Post Office Department. Sheets were exposed on post offices in several large cities and subsequently compared at the Bureau. The use of sheet steel containing from 0.15 to 0.25 per cent of copper was recommended.

Protective Metallic Coatings.

For various branches of the War and Navy Departments tests were made of numerous samples of metal rustproofed by different companies and by different methods.

The method of stripping zinc-coated metal referred to in last year's report—by means of sulphuric acid and sodium bichromate—has been critically examined and found to be unsatisfactory for commercial application. However, careful application of the test will give a fair estimate of the amount of zinc applied.

Salt-spray tests on aluminum alloys, started in 1917 in cooperation with the metallurgy division, were completed and reported upon in Technologic Papers Nos. 132 and 139.

Corrosion tests were made for the Engineering Division of the Ordnance Department on German silver and "aluminized" (tin-coated) steel hinges for meat cans. Considering the advantages of using steel. the tin-coated hinges were regarded as superior to those of German silver, but, in order to conserve tin, zinc-coated steel was recommended.

A test for pinholes in lead plating was developed to indicate a satisfactory lead lining for gas shells. This consists in immersing the plated steel in a solution containing 1 per cent of sodium ferricyanide and 2 per cent of sulphuric acid. Pinholes are indicated by the appearance of a characteristic blue precipitate.

Bituminous Materials.

Roofing.—The preparation of a standard specification for prepared roofing discussed in last year's report became a reality; in conjunction with the War Trade Board the specification was prepared and adopted. It included methods for inspection, testing, and instructions for inspectors; but with the cessation of the war the need of maintaining a corps of inspectors at the plants passed. Millions of squares of roofs obtained under this specification but laid under high pressure failed in many cases to be satisfactory; leaks developed which at first were blamed on the quality of the roofing used, but from inspection it was evident that the fault was with the manner of laying and not the material. The development of a satisfactory bituminous cement to repair the leaks enabled effective repairs to be made at a very moderate cost.

Specifications for slate-surfaced and asphalt shingles were also prepared, but the specification for built-up roofing, which is required under normal conditions, still remains to be developed, nor has it been possible to make a systematic inspection of the repaired roofs which have been laid, and it will be unfortunate to lose this information, which is necessary to improve the specifications which have been in use.

Interior coating for steel ships.—The specification for the coating of the interior of steel ships prepared originally for the United States Navy Yard at Philadelphia, and extended to apply to the bituminous enamel used on the lock gates at Panama, has been modified by restricting the quantity of mineral filler and controlling the consistency of the development of a test which measures this condition so as to improve the specification. This material has also found a use for steel ships being built by the Emergency Fleet Corporation.

Interior coating for steel shells.—The Ordnance Department of the Army asked for a specification for an inside coating for high-explosive shells and shrapnel. This coating should be free from any lead or managenese compounds; it should not dry hard, but remain tacky, so as to bond with the molten T. N. T. with which the shells were charged; and should not have any effect on the efficiency of the explosive. A Gilsonite fluxed with a soft Bermudez asphalt and thinned with a light volatile petroleum product appeared to give a satisfactory coating.

Coating for grenades.—The Ordnance Department also desired a coating for hand and rifle grenades. Hand and rifle grenades require a coating which will dry hard on a greasy surface, as it is not practicable to clean them after machining. A hot coal-tar pitch of relatively low penetration and high melting point was being developed for this purpose when the closing of hostilities practically stopped production of grenades.

Coatings for Concrete Ships.

The concrete ship was a new venture and required special treatment. A ship is subjected to great and various strains and can not be made perfectly rigid. Concrete is usually considered a rigid material, but in fact it is elastic, and if it is properly reinforced it will stand much distortion without failure. Small hair cracks may develop, and it was the problem to cover the outside of the structure with an elastic waterproof membrane which would bridge such small cracks. The coating must not be affected by water, must not flow when subjected to the pressure of the water when the vessel runs at maximum speed, and must present a suitable surface for the application of antifouling, boot-topping, and camouflage paints over it. All of these conditions were considered, and a number of products tested in an effort to obtain one which seemed to best meet conditions of service. Two compositions were recommended, and further work is in progress.

Another problem in connection with the concrete ships was to provide an inside coating for oil tanks. Many of these ships were to be used as oil tankers for the transportation of a variety of crude and refined oils. The problem was complicated by the presence of water in the oil, and also by the fact that these tanks might frequently be filled with water as ballast on return trips, so the coating must be resistant to both water and oil. After an extended investigation it was recommended that a Chinawood oil-resin varnish, commonly called "spar" varnish, was the best available material. This, however, is not entirely satisfactory, and nothing better has yet been tried. It is believed that failures have been more due to faulty methods of application and to expecting more than could possibly be obtained from a paintlike coating than to actual inferiority of material used. Probably the life of the best coatings available will always be short.

Marine Glue.

In an attempt to meet the requirement of the Naval Hydroplane Service for a marine glue for pontoons the original Jeffreys marine glue, made in England, was examined, as well as the present foreign product and domestic substitutes, in the hope that a material might be developed which would make this country independent of foreign production. Neither the present foreign product nor the domestic substitutes were found to be entirely satisfactory, but it was found that Manila or similar varnish resins, with pine tar and rubber, thinned to proper consistency, also blown Mexican or Texas asphalts with gilsonite and a mineral filler thinned to proper consistency were satisfactory.

Linoleum Cement.

The Bureau of Construction and Repair, Navy Department, desired information on linoleum cement. It was found that the shellac cements, with alcohol as a thinner and with or without a finely powdered mineral filler, were more waterproof and held the linoleum more tenaciously to the concrete or steel than those cements made from dextrin or other water-soluble gums or from other resins cut in alcohol. Shellac cements with mineral filler adhered more tenaciously and did not become brittle on drying, as did shellac cut in alcohol without the filler. When water-soluble pastes were used it was recommended that a strip 1 foot on either side of the seams and edges should be cemented with a waterproof cement to keep out moisture and thus prevent the paste from molding. The Bureau of Construction and Repair have reported since the above recommendation that the failure of the water-soluble pastes was due to moisture in the cement floor, and when this was prevented by thorough drying they were justified in accepting the guarantee of the contractor, and have used this cheaper type of linoleum cement.

Oakum.

A specification was also developed through cooperation with the textile division for oakum for the Emergency Fleet Corporation, which, as far as can be learned, is the first definite specification for this material.

Separation of Benzol, Toluol, and Xylol.

As a result of the investigation made at the Roberts coke ovens at Canal Dover, Ohio, a laboratory form of still head has been devised which gives remarkably sharp separation of benzol, toluol, and xylol. This still head will be described in a technologic paper. It furnishes a laboratory method for the separation of these compounds and may have an application in their industrial separation.

Cement.

About 8,000 samples of cement were tested in the chemistry division. Full details of the Bureau's work on cement, including that of the chemistry division, are given in the report on cement, etc. (p. 195.)

Miscellaneous Tests.

For the Railroad Administration some 60 samples of boiler-feed water, boiler scale, and boiler compounds were analyzed to show, if possible, the merits of the Perolin treatment for boiler waters. This work is still in progress.

Many miscellaneous analyses and tests were made, covering soldering and welding fluxes, magnesia-asbestos preparations, furnace cements, aluminum sulphate for treating water, water from military camps, protective backing for mirrored surfaces, fire-extinguishing liquids, etc.

PAINT, VARNISH, AND SOAP.

(Chemical analysis, testing, and exposure tests of paint and varnish; chemical analysis of and specifications for soap.)

Paint Specifications.

Interdepartmental Committee on Paint Specification Standardization.—At the suggestion of the War Industries Board that the Department of Commerce attempt to prepare uniform standard specifications for paint materials, a conference of representatives of all the interested branches of the Government service was held at the Bureau on February 26, 1919. This conference recommended that an interdepartmental committee on paint-specification standardization be organized. This committee was organized and at present consists of one representative each from the War, Navy, Interior, Treasury, Post Office, Agriculture, and Commerce Departments, the

Panama Canal, Railroad Administration, and the Paint Manufacturers' Association. This committee has held a number of meetings and has prepared and recommended the specification for linseed oil, raw, refined, and boiled, which has been issued as Bureau Circular No. 82. The committee is considering specifications for other paint materials, and it is hoped that a number of such specifications will be issued within the next year.

Miscellaneous Paint Specifications.—A great number of miscellaneous paint materials specifications have been prepared. Mention may be made of two.

The War Industries Board requested specifications for paint to be used in housing projects for the Government and that an especial attempt be made to have these specifications cover the use of materials entirely of American origin. As a result of our cooperation with manufacturers and other experts, the War Industries Board paint committee recommended to the Housing Corporation specifications for a number of paints to be used on wooden houses.

In accordance with a request from the Forest Service, Department of Agriculture, specifications for white, cream, drab, cinnamon-brown, and green paints were furnished.

Projectile Paints.—In the latter part of the fiscal year ending June 30, 1918, and extending over to the present fiscal year, a large number of samples of very rapid drying paints for use on projectiles were tested at the request of War Department officials, and specifications were prepared and sent to the Edgewood Arsenal, Baltimore. Paints covered by this specification are very rapid-drying and were designed for use during periods of heavy production. The War Department, however, has specifications for projectile paint of a different nature than the above-mentioned, being much slower in drying, and the Bureau has not been able to learn which type of paint has been actually used by the War Department, although it would appear that the type contemplated by the Bureau's specification is far superior for periods of intense production than the material specified by the War Department.

Protective Coatings for Ordnance Stores.

After the signing of the armistice the Ordnance Department asked for advice relative to the painting of guns, shells, and other equipment for storage. Experiments were carried out to determine the thickness of films on shells after brushing and spraying, and it was found that three coats of paint could be applied to shells without increasing the diameter to exceed the tolerances permitted. Recommendations were made as to the character of paint to be used for storing this type of equipment.

In addition to requests from the Army officers regarding methods of painting ordnance stores, a large number of requests came in regarding the use of oily coatings generally known as slushing oils. Formerly these materials were used for protecting bright parts of machinery for only short periods, and there is no information available as to the length of time that such coatings will afford protection. After examining a large number of samples of such materials, some mimeographed notes on protecting metal in storage were furnished to a large number of Army officers. They contain a general statement of the nature of such materials and proposed specifications for three types.

Tests of Water Resistance of Enamels and Varnishes.

A very large number of samples of enamels and varnishes which were used on naval aircraft were tested for the Navy Department with a view to getting the most waterproof and durable coating to apply to wooden parts of airplanes. The net results of these tests seem to indicate than an enamel made of a vehicle of spar varnish and a pigment containing a considerable quantity of white lead is about the most satisfactory material available. The specifications were, however, at the Bureau's advice, changed so as to cover physical requirements and eliminating definite requirements as to composition of pigment.

Fireproofing Fiber Board.

Some of the Army hospitals were made of a waterproofed wood-fiber board known as Insulite. This construction proved to be a very great fire hazard and at the request of the Construction Division of the Army investigations in cooperation with the Heat Division, with the object of lessening the fire risk, were made. It was found that a solution of water glass was the most successful treatment tried, and diminished the fire risk somewhat, but the danger from fire will always be very great with this type of construction. It was recommended that, as far as possible, the buildings constructed of this board be discarded and further use of this building material be discontinued, but that where the buildings could not be vacated all the interior walls be treated with a spray coat of a solution of water glass.

Carbon-Tetrachloride Fire-Extinguishing Liquid.

At the request of the War Industries Board and the Quartermaster General, War Department, experiments were made to find a substitute for chloroform as a freezing-point depressant in carbon-tetrachloride fire-extinguishing liquids. It was found that gasoline and turpentine were both efficient, and the resulting mixtures were fire-extinguishing liquids. It is believed that the use of these depressants would have resulted in a very great saving in money to the War Department, but the signing of the armistice removed the necessity for the conservation of chloroform, which was the material previously specified as a freezing-point depressant, and it is doubtful whether gasoline and turpentine will be used for this purpose in normal times.

Soap.

A great many samples of soap have been examined for all branches of the Government service. Additional specifications were prepared and a new edition of Circular No. 62, containing additional suggested specifications, was issued. In addition to the specifications given in the circular, others for shaving cream were prepared for the Purchase, Storage and Traffic Division of the War Department, and the Bureau is informed unofficially that these have been practically adopted. In connection with these soap specifications it may be mentioned that shaving cream and liquid soap are materials which the Bureau does not recommend. It is believed that the liquid soap is not as satisfactory as cake soap and the shaving cream is far more expensive than other types of shaving soap. There seems to be a demand for these articles; hence the specifications were prepared.

Linseed Oil.

Linseed oil is the most important liquid used in the paint and varnish industry. It is, therefore, very important to not only have adequate determinations for purity, but to develop some tests for quality of oil of undoubted purity, since there is a great difference in the value of different lots of linseed oil of undoubted purity. It appears that the presence of foots is the most probable cause of inferiority in pure linseed oil. The test for foots was developed in this laboratory some years ago and has been incorporated in recent specifications.

The most important determination in ascertaining the purity of linseed oil is the iodine number. Unfortunately, there is quite a wide range in the iodine numbers of pure linseed oils from different parts of the world. It is, therefore, possible, with present methods, to skillfully adulterate linseed oil of high iodine number with other oils and pass the mixture as pure. The determination of the percentage of insoluble hexabromides has been frequently recommended as a much more reliable method of determining adulteration than the iodine number. Unfortunately, all the published methods for the determination of hexabromide have been faulty in that different analysts could not get concordant results with them. In the last few months some important work on this determination has been done in this laboratory and a tentative method prepared which is being tested in a number of other laboratories. It is believed that the defects of the older methods have been largely overcome and it is hoped that this method may prove of great value to the oil analyst.

Miscellaneous.

Among minor problems handled may be mentioned determination of carbon in pigment, varnish for rifle and hand grenades, tests of proposed gasoline substitutes, and many other such problems.

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.]

MECHANICAL APPLIANCES.

(Investigation and calibration of special mechanical appliances; development of methods and apparatus for standardizing the performance of such appliances; investigation of operative efficiency of mechanical appliances, such as fire extinguishers, radiator traps, vacuum cleaners, etc.)

Fire-Extinguisher Investigations and Tests.

An investigation of hand chemical fire extinguishers and similar apparatus, undertaken several years ago at the request of the Steamboat-Inspection Service, to determine the merits of devices of this character intended for use on vessels under its jurisdiction, was continued to include the investigation and test of apparatus offered for inclusion in its approved list during the past year.

A total of 78 fire extinguishers of various types were tested for the different Government departments.

The necessity for fire protection of gasoline-driven vehicles, airplanes, and similar risks where low temperatures may be encountered and other conditions of service preclude the use of older forms of apparatus depending on solutions of water, has resulted in the development of a 1-quart liquid-chemical extinguisher using an extinguishing agent consisting principally of carbon tetrachloride. Extinguishers of this type are peculiarly subject to deterioration after a short time in service. At the request of the Bureau of Construction and Repair, Navy Department, an investigation was made of extinguishers of this type to supply data to be used as a basis for establishing an approved list for the purchase of such devices. Results of tests conducted for this purpose, including tests after six months in service, on a number of samples of seven different makes of extinguishers showed the majority of the brands tested to be unsuited for the purpose intended.

To conserve the supply during the period of the war of certain chemicals used in fire-extinguishing fluids, a series of fire tests was made, in cooperation with the chemical division, to determine the effectiveness of substitutes proposed for this purpose.

A member of the section served on a committee of the War Department for the standardization of fire apparatus.

Comparative Test of Roof Ventilators.

For the equipment of cantonments, hospitals, and other buildings it was necessary for the Army to purchase large numbers of roof ventilators. No reliable test data as to the efficiency of the various types and makes offered for sale were available. At the request of the Construction Division of the Army, a comparative test of some 33 different 18-inch ventilators was made in the Bureau's wind tunnel. The comparative efficiency of the different samples in exhausting air at different wind velocities under identical conditions for each ventilator was determined and a report submitted, in which the various makes of ventilators were listed, in the order of their merit, for the guidance of the purchasing officers.

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 heating system is principally dependent on the successful operation of these valves, one of which is connected to each radiator outlet. Tests are made under different working conditions to determine whether 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 waste resulting through the escape of uncondensed steam to the return line.

Performance specifications for these valves have been formulated and are being used by the Treasury and other Government departments in the purchase of equipment of this character.

Miscellaneous Tests of Mechanical Appliances and Equipment.

Numerous miscellaneous tests of mechanical appliances were made of a more or less extended character, including a series of tests of relief disk and fusible plugs of high-pressure valves for use on hydrogen cylinders, and numerous tests of powder containers for the War Department, tests of reducing valves, steel tubing, flexible metallic hose, relief valves, pipe fittings, etc., for the various Government departments and for private firms.

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.

In the development of the water resources of the country in power development, irrigation, flood prevention, and similar projects an accurate knowledge of the quantity of water being discharged through rivers and other open channels is essential. These data are based on measurements of the velocity of the flowing water made with current meters. To insure the accuracy of these measurements, these instruments must be periodically calibrated by towing tests in still water.

Installations satisfactory for this purpose, involving the use of a body of still water and suitable means of propelling the meter through the water over a range of uniform velocities, together with instruments for making the necessary observations, are so costly as to be practically limited to Government stations or those at large universities. The inclosed rating station maintained for this purpose at the Bureau furnishes exceptional facilities for the calibration and study of these instruments.

During the past fiscal year a total of 184 current-meter ratings were made for engineers in Government and private service.

A series of tests was made of two experimental meters submitted to the Bureau to determine their suitability for the special purpose for which they were designed.

Calibration of Engineering Instruments.

During the fiscal year calibrations were made of 201 pressure and vacuum test gauges, including gauges for the measurement of pressures up to 30,000 pounds per square inch, 12 tachometers, 10 anemometers, and a number of miscellaneous tests of instruments, including indicators, speedometers, etc.

Theory of Measuring Instruments.

The work on this subject discussed in the last annual report has been continued. The errors commonly known as calibration errors, when they are repeated consistently on successive readings, are not seriously detrimental in the laboratory use of measuring instruments, as they can be corrected by simple calculation. Variant errors, on the contrary, are characterized by failure to repeat their values on repeated trials, and hence their correction requires special analysis and treatment. The research which was originally intended to lay down specific definition and formulation of the variant errors of measuring instruments has resulted, in addition, in the development of a method by which the accuracy of determinations made with indicating instruments under certain specified conditions of use and manipulation can be signally increased, oftentimes fiftyfold. In connection with this work it was shown that when the conditions surrounding the use of an instrument are subject to control in certain simple respects even an instrument of crude and inaccurate construction can be made to furnish results of surprisingly accurate character. The researches forming the experimental basis for this method have been published in one of the scientific periodicals.

The general principles developed during this investigation have also resulted in a new method of specifying the performance of a wide range of measuring instruments. Thus it was shown that an indicating instrument is analogous to a specimen of structural material under stress, in that the occasioning of a deflection, after cyclic operation has been set up, implies the storing up of a definite amount of mechanical or other energy in the instrument. The completeness with which the stored energy is restored when the deflection is again reduced to zero may be called the "resilience" of the instrument and affords a useful measure of the perfection of the instrument as regards the consistency or reproducibility of its determinations. This is a result of the fact that all causes which produce variability, or, as it may now be more exactly termed, variancy, of a sort which is inherent in the operation of an instrument itself, rather than in its environment, can be correlated with energy dissipation due to the imperfect "elasticity" or the energy-transformation inefficiency of an instrument. The relative magnitudes of this energy loss for instruments of different types designed for similar purposes afford a criterion of quality which is in large measure effective in establishing a definite basis for selection of an instrument for a given purpose.

These studies have been extended to determine the effect of vibration, or tapping, upon the indications of an instrument, and it was found possible to establish the general relation of the calibration obtained under these conditions to that obtained when the instrument is operated slowly and aperiodically without jarring. A general discussion of the subject of the variance of measuring instruments, with suggestions for its numerical specification and for its correction in laboratory practice, was presented before a scientific society by the Bureau's expert in this field.

The immediate application of these results is to instruments of the so-called indicating types, in which the momentary value of the quantity measured is shown (as a pressure gauge or a weighing scale), rather than to those of the integrating or totalizing type, in which the summation or total of the values registered up to the time of observation is recorded (as a watt-hour meter or a clock). These investigations have shown the necessity for exact definitions of a number of the terms entering into the specification of instrument performance, including accuracy, sensitiveness, passiveness, hysteresis, lag, resilience, variance, gross precision, and effective or useful precision. A publication is, therefore, being prepared in which all these terms will be clearly set forth and discriminated and a method for the definite performance rating of instruments will be outlined.

AERONAUTIC INSTRUMENTS.

(Investigation, testing, and experimental development work on all types of aircraft instruments, including altitude-measuring instruments, rate-of-climb indicators, engine-speed and air-speed indicators, airplane-pressure gauges, gasoline-supply gauges, inclinometers, banking indicators, turn indicators, bomb sights, and oxygen-control apparatus; also mercurial barometers, weather and surveying aneroids and sphygmomanometers; development of methods of testing, improvement in design of such instruments, fundamental researches on the physical principles of such instruments, study of their operation in actual service, and determination of corrections required for aircraft-performance tests.)

Fundamental Theoretical Work.

There are various instruments which have some physical problems in common. These have been solved once for all by general mathematical methods, so that the results can be applied to individual cases as they arise. Problems concerning the flow of fluids which may be met in the rate-of-climb indicator, in air-speed indicators, and in oxygen-control apparatus form one such group. Another is the determination of the combined effect of thermal expansion and change of elasticity with temperature on instruments constructed with springs and diaphragms. A third group deals with the theory of errors. The results of such investigations are to be found in Scientific Paper No. 331, A Relation Connecting the Derivatives of Physical Quantities, and in the technical information circulars referred to below.

Development of Standard Testing Equipment.

Recommendations for standard testing outfits and procedure for testing altimeters have been furnished at the request of the French Government, the Canadian Government, the United States Navy, the Engineer Corps, and the Bureau of Aircraft Production of the United States Army. In the last instance the first barometers needed were designed and constructed by the Bureau; later orders were filled commercially on the basis of Bureau of Standards' specifications. The first equipment available for testing oxygen apparatus was also developed by the Bureau and adopted by the Army and the instrument manufacturers. In addition to such equipment, which was developed for use in production and inspection work, the Bureau's own standards, necessarily of a more refined degree of accuracy, were further improved during the year. For example, in the tachometer laboratory a standard test set was constructed in which a master tachometer of the liquid type, carefully studied for temperature errors and lag, is connected to a large motor-driven flywheel to insure steadiness of indications; and for checking it against the standard time signals of the Bureau an automatic electro-magnetic clutch was devised. To facilitate testing tachometers in quantity, a multiple-connection drive was made. A large sound-proof chamber was built for the continuous running of vibration tests with a minimum of disturbance to the other workers in a seriously overcrowded laboratory. A vacuum chamber with mercury-seal connections for the driving-shaft was constructed for testing certain tachometers under altitude conditions. Similar improvements were developed in all the other laboratories of the section. In addition, methods for testing rate-of-climb indicators and gyroscopic-turn indicators were originated during the year.

Construction and Performance Specifications.

On the occasion of a trip to Europe six years ago a comparison was made between the British, French, and German performance specifications for aneroid barometers and those issued by the Bureau. Soon after our country entered the war a critical study was made of the British specifications for standard airplane instruments which had been placed at the disposal of the aeronautic instruments section of the Bureau by the Royal Flying Corps. At the same time a survey was made of the manufacturing facilities of the country. Thus the Bureau was already prepared, when called upon by our aviation authorities, to give advice in regard to instrument production and to render expert assistance in preparing specifications. As a result all the instruments adopted as standard by the Army and Navy were based directly or indirectly on specifications originating in the Bureau. During the past year this work has been continued.

Researches on the Errors of Instruments.

Aside from the ordinary errors met in engineering instruments, such as incorrect calibration, parallax, looseness or friction in the mechanism, elastic hysteresis, and secular changes, those used on aircraft may be further influenced by the physical conditions peculiar to aviation, viz, (1) extreme drop of atmospheric pressure, (2) extreme change in temperature, (3) vibration, (4) acceleration or inclination. For example, a pressure gauge of the Bourdon-tube type suitable for the engine room may not be accurate when chilled much below the freezing point; and a tachometer of the air-viscosity type, perfectly suitable as an automobile speedometer, may show from 5 to 10 per cent drop in reading at a pressure corresponding to an altitude of 25,000 feet. Experiments to determine the characteristic errors of different types of construction for each of the various instruments have been continued and extended during the year. Such investigations are, perhaps, the most essential feature of the laboratory work of the section, and have been of especial importance during the war on account of the tendency for the errors to get larger whenever production is speeded up. The results provide a basis for performance specifications, for improvements in design or in production processes, and for estimating the corrections of instruments in use. In the case of altimeters, tachometers, and air-speed indicators the foregoing data have been supplemented by a statistical analysis of the results of the routine tests. Of especial interest during the past year may be mentioned a comparative study of the various physically different types of tachometers (chronometric, centrifugal, magnetic, electric, air-impulse, air-viscosity, and liquid types); a determination of complete corrections for the barographs employed in a flight which established a world's altitude record; and an experimental study of Venturi tubes. The latter comprised experiments in a water channel and in a so-called vacuum wind tunnel, for the observation of effects due to the density, viscosity, and compressibility of the medium. It will serve as a starting point later for the computation of altitude corrections for air-speed indicators.

Flight Tests on Airplane Instruments.

Taking with him in an airplane instruments previously studied in the laboratory, the expert physicist is able to observe and explain peculiarities in their behavior which might pass unnoticed by the aviator, yet prove serious later. Such a flight was made in 1913 before any instruments distinctively designed for airplane use were yet on the market, and they have been continued at intervals during the war in cooperation with the aviation authorities. Among those made during the summer and fall of 1918 was a seaplane flight on a dark night for the demonstration of a projection type of night-altitude indicator; also a trip across the Channel from England to France, at which time a comparison was made between the British and American compass; a performance test of an airplane 3 miles up over the suburbs of Paris; a series of high-altitude flights for the study of oxygen apparatus; flights for the testing of rate-of-climb indicators; and flights for the testing of gyroscopic and other inclinometers.

Instrument Collection.

Extensive additions have recently been made to the collection of aircraft instruments, including a barograph of exceptional design by De Giglio, of Turin; a large French compass with unique mechanical features for use on dirigibles; and a combination German instrument containing fore-and-aft inclinometer, banking indicator, and gyroscopic-turn indicator. This collection has been of value for instruction, investigation, and instrument production, and undoubtedly is now one of the most complete in the world.

Salvage Methods.

A study has been made of practical methods for repairing defective or damaged instruments, with particular reference to expedients for readjusting the mechanism so as to give a correct calibration, a more uniform scale, or a satisfactory degree of temperature compensation. Such work, especially on recording instruments, has at times been done at the Bureau, and the information has proved of value to American manufacturers and to our salvage officers and mechanics at flying fields here and in France.

Study of European Instruments and Methods of Testing.

With the authority of the Secretary of War and Secretary of the Navy, a representative of the Bureau made a visit to the establishments of the American forces abroad, leaving in August, 1918, and including some of the principal airdromes, factories, and laboratories of the allied Governments in England, France, and Italy. This trip afforded an exchange of the latest technical information and provided first-hand knowledge of conditions attending the use of aeronautic instruments in military and naval operations. The reports of the Bureau's instrument investigations proved to be of interest at all points visited, and some of them were immediately duplicated or translated for confidential use. In return, valuable information and samples of instruments and materials were made available to the Bureau, and a number of urgent experimental problems were proposed for the Bureau to take up. As an aid in the study of the technique of instrument testing, eight typical American instruments (altimeter, air-speed indicator, compass, thermometer, two pressure gauges, and two tachometers) which had previously been tested at the Bureau were taken over and submitted for test at the Royal Aircraft Establishment in England, and elsewhere. The success of the trip was largely due to the cordial cooperation of Maj. George M. Brett, chief of the airplane instrument and testing division of the American Air Service in France.

Instrument Instruction for Aviation Officers.

At the request of the Navy Department a school of aeronautic instruments for navigation officers was conducted by the section in the fall of 1918. This was an intensive course of three weeks' lecture and laboratory work covering the theory and testing of the various instruments and concluding with a written examination. A somewhat similar, though shorter, course had been given the previous year. Information and photographic material has also been furnished for the use of the Army in instruction courses for military aviators.

Experimental Development Work.

1. Drawings were made for a recording air-speed indicator with metallic diaphragms.
2. The problem of ground-speed measurement by dynamical or other methods not depending on the visibility of the ground has been investigated and a model illustrating the principle of one such type has been constructed. Such instruments require stabilization.
3. Detail drawings of a gyro stabilizer for instruments had been prepared at the time of the armistice and a working model of about one-fourth size constructed. A bomb sight and double-pivot compass to go on the stabilizer formed a part of the design. The continuance of this work would be of value for navigation purposes. The double-pivot compass appears to be the only suggestion thus far put forward for theoretically eliminating the "northerly turning error."
4. Inclinometers of the liquid type have been constructed for the National Advisory Committee for Aeronautics and two new types of banking indicator developed by the Bureau.
5. By engraving special dials and redesigning the mechanisms certain altimeters submitted by the Army, Navy, and National Advisory Committee for Aeronautics have been converted into instruments more suited for performance tests on aircraft.
6. The conversion of low-altitude into high-altitude barographs by the Bureau's method has been continued at the request of the Army.
7. A study has been made of the possibilities of different principles for recording airplane vibrations, including the piezoelectric effect, and several trial vibrometers constructed. In this connection a new type of vibrating stand has been developed which has greater adjustability than previous forms, and which does not subject the driving motor itself to the vibrations; also a model has been constructed illustrating the theory of so designing the movable parts of instrument mechanism as to balance them against the effect of sudden angular accelerations, such as chiefly compose the instrument-board vibrations of an airplane.
8. A new feature in oxygen-control instruments, which would avoid the main source of temperature error, was developed.
9. A preliminary model of an improved centrifugal tachometer has been constructed and found promising in several particulars.
10. A start has been made on the experimental work in connection

with the construction of a large open-scale altimeter at the request of the National Advisory Committee for Aeronautics. Such an instrument, though not a commercial proposition, is greatly needed in aircraft-performance tests. In connection with the work of the altimeter laboratory, a study has been made of the possibility of combining thermometric and pressure elements into a single mechanism. One such combination would afford a true altitude meter, whereas the existing altimeters assume a fixed temperature for the atmosphere and require the computation of large corrections. Another combination mechanism would give a direct-reading density meter. Three methods also have been proposed for avoiding the evil of elastic fatigue in altimeters. One consists in providing an auxiliary instrument with a very open scale reading only to 1,000 feet, above which point it is automatically shut off from the atmosphere, and thus protected from the strain which causes fatigue. A second consists in making the steel mainspring of the altimeter so much stiffer than the diaphragms that the latter, however poor the material may be, can only contribute a small proportion of the observed result; this method is made possible as a result of experiments which have shown that the steel springs of good commerical aneroids have only an insignificant amount of fatigue in comparison with the diaphragms. A third method is the obvious, but less immediate, one of developing eventually better materials or designs for the diaphragms. This is described under (14) below.

11. A rate-of-climb indicator has been developed, using thin metallic diaphragms in place of the usual liquid manometer. The latter has the disadvantage that the readings are seriously affected by inclination and acceleration. A comparative test in airplane flight was in favor of the Bureau's instrument, except for the time lag, which should be further investigated.

12. In addition to the electric-spark-recording process, other ink substitutes have been studied and a successful radium method developed. In this connection plans have been made also for the use of the moving-picture camera for securing a record of the instrument readings during an airplane-performance test.

13. Altimeter chains have been studied by a special life-testing device, and the superiority of gold chains thus far indicated.

14. Diaphragms have been spun in the instrument-development shop of the section and given a mechanical aging treatment. This process has been found more effective than heat treatment in reducing the elastic feature of unseasoned material. The elastic properties of a large number of diaphragms, made from alloys selected in consultation with the metallurgy division, have been measured in the hope of producing a material or a design superior to those in commercial use. This work has been done at the request of the National Advisory Committee for Aeronautics, and is to be continued.

Testing of Aeronautic Instruments.

During the past 12 months 578 tests have been made on instruments submitted from outside. The value of these tests on the basis of the Bureau's fee schedule would aggregate about $10,000. They were distributed as follows: 148 altimeters, 63 barographs, 50 statoscopes, 6 mercurial barometers, 74 air-speed indicators, 59 sets of oxygen apparatus, 134 tachometers, 18 pressure gauges, and 26 special instruments or appliances. The latter comprised 2 gasoline-depth gauges, 2 aerographs, 8 reducing valves, 5 aneroid stacks, 2 unit sights, 2 inclinometers, 1 electromagnetic rate-of-climb indicator, 1 night altitude indicator, 2 bomb sight speed regulators, and 1 gyroscopic-turn indicator. Practically all the tests included endurance runs or some other feature making them more complete than the factory-inspection tests. Many of them were in the nature of short investigations to determine the suitability of new types of instruments for production. In addition, 95 thermometers and 9 compasses were tested by the heat division and the electrical division of the Bureau. The list does not include tests made on instruments developed by the Bureau, nor upon instruments submitted solely for the collection.

Technical Information Circulars.

The series of aeronautic-instruments circulars for confidential distribution begun the previous year has been continued. These documents are duplicated for temporary use and serve to make the results of the Bureau's investigations immediately available to authorized persons. The following were issued during the year: Spinning-Top Inclinometers; Historical Notes on Aneroid Barometers; Two Aneroids Tested in England, France, Germany, and the United States; Methods for Testing Aneroid Barometers; Testing Methods for Airplane Tachometers; Air-Speed Indicators; Statoscopes and Climbing Indicators; List of American Instrument Manufacturers; High-Altitude Barographs; Report on a Group of British Instruments; Report on a Group of Danish Instruments; Methods for Testing Air-Speed Indicators; Gasoline-Level Gauges; Airplane Pressure Gauges; Instruments Tested January 1 to June 30, 1918; Inclinometers; Airplane Tachometers; The Theory of Dimensions with Applications to Instrument Work; A Theory of Irreversible Time Effects, with Applications to Instrument Work; Mechanical Design of Aneroid Barometers; Temperature Compensation of Aneroid Barometers; A Night Altitude Indicator; A Proposed Plan for Bomb Sighting; Airplane Thermometers (contributed by the heat division of the Bureau); Report on a Group of American Instruments Tested Abroad. Owing to the limitations of the Bureau's photographic service, it has not been found possible to keep up with the demand for this material, even though it has not yet been publicly announced as available.

Correspondence and Conferences.

Much information and advice has also been given out in reply to official correspondence and in response to verbal requests. A considerable part of this consisted in the examination of inventions in connection with aeronautic instruments and other appliances submitted by the General Staff of the Army and by the National Advisory Committee for Aeronautics. Members of the section individually conversant with some particular branch of physics, as elasticity, capillarity, viscosity, high-pressure measurements, or the theory of errors, have frequently been called upon for conferences with visitors or for cooperation with some other section of the Bureau. During the summer of 1918 the section was visited practically every day by production officials of the Army or Navy to follow the results of investigations or discuss specifications, with occasional visits also from foreign delegations. And in accordance with the Bureau's policy of cooperation with other organizations the chief of the section has served, by request, on the subcommittee for lubrication of the research committee of the American Society of Mechanical Engineers; on the airplane-instruments committee of the International Aircraft Standards Board; and on the aerodynamics committee of the National Advisory Committee for Aeronautics.

Cooperation with American Manufacturers.

The Bureau has been of assistance in building up an American instrument industry not only by carrying out fundamental researches which no single manufacturer could undertake but also by continuously helping manufacturers to improve their product in matters of detail. This has been accomplished by frequent informal conferences at the Bureau and in the factories, and at times also by telegraphic reports. At one time a certain manufacturer complained that the Bureau's performance specifications for barographs, on which his contract was based, were too strict in their requirement for temperature compensation and wished to have instruments accepted which were four or five times over the limit. Before reconsidering any tolerances the Bureau's expert was sent to the factory with scientific suggestions for diminishing the error in question. Less than two months later this manufacturer was successfully producing instruments averaging only one-half the temperature error permitted by the specifications. This experience is merely typical of many other instances.

Cooperation with American Physical Society.

At the request of the society this section contributed several papers by title at the spring meeting on war problems, three of which were presented in full, dealing, respectively, with general investigations of air-speed indicators, tachometers, and altitude instruments. A large exhibit of instruments and testing appliances was shown at the same time as a part of the society's exhibition. This included tachometers, gyroscopic instruments, a rate-of-climb indicator, and other devices in actual operation.

Cooperation with National Advisory Committee for Aeronautics.

This section has cooperated continuously with the Advisory Committee, avoiding duplication of Government facilities by serving in effect as the instrument laboratory of the committee. A considerable group of aeronautic instruments, together with graphical charts, also a whirling table of banking indicators, a vibration stand, and a chain-testing outfit, all kept in motion by electrical connections, were contributed to the exhibit of the Advisory Committee at the Manufacturers' Aircraft Exposition in New York.

Future Development of Aeronautic Instruments Work.

The instruments of an airplane or dirigible are its sense organs. It can fly without them, but only blindly. When one considers the ever present danger of a crash in the fog, together with the high cost of the large aircraft now coming into use, any reasonable expenditure for improving the reliability of the instruments justifies itself at once, even without taking into account the value of human life. A further need for instrument investigation comes from the fact that those types of instruments which are adapted for measuring aircraft performance underlie the whole future development of aeronautical engineering, since this all goes back in the end to questions of measurement. For these two reasons alone no financial investment in aeronautics of any moderate magnitude could be more productive than one devoted to the advancement of instrument work.

AERODYNAMICS.

(Fundamental data of aerodynamic physics as applied to the study of the resistance of air to the motion of bodies, including 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 the testing of airplane equipment and other apparatus functioning in an air stream.)

Wind-Tunnel Investigations.

The Bureau now has in operation two wind tunnels of the open type, the larger of which is well adapted for the testing of model airplanes and wing sections, while the other, and smaller one, is used in the testing of airplane equipment in which the attainment of high air speeds is necessary.

The 54-inch octagonal tunnel is housed in a room 79 feet long, 29 feet wide, and 18 feet high, and is equipped with two weighing balances. One balance is of heavy construction and is designed for the measurement of lift and drag forces on heavy models, such as air bombs and engine radiator sections. The second balance is much more sensitive, and is used primarily in the determination of the characteristics of aerofoils and airplane models. From these models test predictions may be made of the behavior in flight of the full-scale machine. In this tunnel air speeds ranging from 5 to 90 miles per hour are obtainable.

To keep pace with modern aircraft developments, the Bureau began in October, 1918, the construction of a high-speed wind tunnel. This tunnel, which was completed and in operation in April, 1919, is of the Venturi type, 36 inches in diameter at the throat or working portion, and is constructed entirely of wood, the tunnel proper being built up of cypress-wood segments. The tunnel was designed for a maximum wind speed of 150 miles per hour at an expenditure of about 100 electrical horsepower. In subsequent tests, however, air speeds of 180 miles per hour were obtained with an expenditure of 120 electrical horsepower. The wind stream is maintained by a tractor propeller, 7 feet in diameter, connected directly to a 125-horsepower direct-current motor. The tunnel is housed in a room 106 feet long, 27 feet wide, and 12 feet high.

Besides work of a distinctly military nature, such as studies of the characteristics of aircraft bombs, time constants of arming vanes, methods of driving aircraft reconnoissance cameras, and calibration of variable-pitch propellers for wireless sets, tests have been made on a number of monoplane, biplane, and triplane models and on a large number of wing sections. These latter included tests on a series of ribbed aerofoils, a series of German wing sections, and a series of aerofoils in connection with the design of an automatic variable camber wing.

Cooperation has been afforded aircraft designers and manufacturers in the calibration of various types of air-speed indicators and in the determination of the characteristics of aerofoils and airplane models.

PHYSICAL OCEANOGRAPHIC INSTRUMENTS.

(Assistance in design and construction of physical oceanographic instruments.)

In cooperation with the scientific work of the International Board on Ice Observation, the facilities of the Bureau have been extended for the design and construction of new oceanographic instruments. A convenient, accurate instrument to measure the saline content of sea water has been designed and constructed and successfully used on shipboard. Any instrument to be used at sea must be simple, convenient, easily operated, and rapid.

An investigation is now in progress to determine the relative accuracies of the several methods of measuring sea-water salinity. Samples of sea water have been forwarded to the Bureau and measurements of these have been made by the chemical, electrical, and density methods, and the results obtained are to be compared with a method of hydrostatic weighing. This work is being done in cooperation with the Bureau of Fisheries.

7. STRUCTURAL, MISCELLANEOUS, AND ENGINEERING MATERIALS.

[Invstigation 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; investigation by means of the strain-gauge of structures under load; 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.)

Variable Camber Airplane Wing.

One of the most important investigations carried on by this section during the past year is that of the variable-camber wing, so named because of its change from stream line to lifting shape with a change in flying speeds. This work was carried on in cooperation with the National Advisory Committee for Aeronautics, who suggested the problem.

With the present form of airplane, it is found that the landing speed is about one-half the maximum attained in flight. If the speed in flight is great, which is particularly the case for military work, the landing speed becomes almost prohibitive.

This wing has been designed so as to assume the cambered or lifting form when the airplane is traveling at low speeds. This change in form is due to the pressure of the air upon the lower surface of the wing. The pressure is caused by the forward motion of the machine with the planes tipped from the horizontal so that their leading edges are about 6 inches above their trailing edges.

The shape of the cambered wings is such that their lifting capacity is great, and their minimum speed low. As the speed increases after a flight is begun, the wings are gradually changed so that the leading edge is brought nearly at the same level as the trailing edge. The pressure of the air upon the variable-camber wing then becomes equal on the upper and lower surfaces, and the wing assumes a stream-line shape which offers only about one-quarter the air resistance of the cambered wing. Any decrease in resistance causes a corresponding increase in the speed of the airplane if the engine thrust is constant, which is practically the case.

In order to determine the behavior of the variable-camber wings when combined with the usual form of wing in both biplane and triplane combinations, models were tested in the wind tunnel at this Bureau. The results of an extended series of experiments showed that their behavior was entirely satisfactory.

This problem has been carried as far as possible in the laboratory, and shows promise of operating satisfactorily in actual use. The work has progressed to the stage where it should be tried in actual airplane construction, first to be sandloaded to prove that its behavior under load is satisfactory, and that the structure possesses the required strength. A variable-camber airplane should then be used to demonstrate its value in actual flight. If expectations are fulfilled, there is no doubt it will prove a great stride forward in airplane progress.

Test of 150-Ton Floating Crane for the Navy.

At the request of the Bureau of Yards and Docks, Navy Department, strain-gauge measurements were taken on some of the important members of a 150-ton (336,000 pounds) revolving floating crane built for use in the navy yard at Norfolk, Va.

This test was made to determine the distribution of stress among the various members of the crane while under load and to obtain a more complete knowledge of the actual amount of stresses in some of the members of this statically indeterminate structure.

This crane represents the most advanced type of revolving floating crane of large capacity. The jib is a tapering Pratt truss, hinged to the superstructure in the lower chord and connected to the luffing screws at the upper chord by suitable links. The length of the links and the location of the luffing screws are such that a nearly direct pull is exerted on the upper chord of the jib for all positions. The superstructure, exclusive of the jib, consists of two subdivided triangular trusses rigidly connected by cross bracing. The entire revolving load is transmitted by the triangular trusses to the pontoon through a pintle, the pintle being an inverted pyramidal shaped member built up on four posts, which transmits its load at the apex to a thrust bearing on the deck of the pontoon. The pintle is supported laterally on a tower consisting of six legs arranged in the form of a hexagon, the legs of the tower being carried through the deck to the framing of the pontoon. The tower is framed into the hull in such a manner as to make the pontoon act as a large girder in resisting the forces induced by a crane load. The pintle rotating within the tower makes it possible to revolve the superstructure with the live load to any position.

Readings were taken at various points of the deck to determine the magnitude and, if possible, the position of the maximum stress in the upper-deck plate; on the tower members, to determine whether the tower acted as a unit; around the manhole in the tower legs, to find the effect of such an opening; on the pintle, to determine the magnitude of the stress in these members; and on various members of the superstructure, to determine the manner in which the loads were carried down to the pintle.

Gauge lines were placed on two opposite sides of every member tested, and, where possible, on all four sides. Gauge lines were laid out on the deck of the pontoon for the purpose of determining the amount of stress developed in the plates of the pontoon deck and to check the computed locations of the maximum bending moments.

Strain-gauge readings were taken with a 10-inch Berry strain gauge, it being possible to read the change of length between the points of the instruments directly to the nearest 0.0002 inch, and by estimation to 0.00002 inch.

The material used for loading the crane consisted chiefly of armor plate and scrap iron of known weight. The loading was so arranged that each member on which measurements were taken was subjected to the maximum possible range of stress.

The strain-gauge work done on this structure showed that all stresses on the various members were within safe limits.

Tests of Motor-Truck Wheels.

In designing class B military truck it was found desirable to develop a metal wheel having the good qualities of all the wheels on the market. As there was not sufficient time to make service tests, this section conducted radial-compression and side-thrust tests upon cast steel, pressed steel, wrought iron, and wood wheels made by various manufacturers. From the data obtained from these tests a cast-steel wheel known as the "composite" wheel was designed. This type of wheel proved satisfactory in test and was, therefore, adopted for use on the class B truck.

Twenty-one wheels were tested. The deformations of the wheels under the radial-compression tests were recorded for four points on the rim spaced 90° apart. Similar data were obtained from the side-thrust or skid tests.

From these test data, the limit of proportionality, ultimate strength, rate of deformation, and elastic resilience were found for each wheel.

Strain-gauge measurements were made upon one cast-steel wheel to determine the stress distribution.

A stress analysis of this kind should prove valuable in the design of wheels, and the many inquiries from wheel manufacturers for these data show their interest in such work.

Tests of Electric Welds.

The urgent need for ships to transport our men and material to Europe during the recent war with Germany made it necessary to adopt every means of securing maximum output from the shipyards of this country. The "fabricated" ship, constructed from plate material on which all cutting and drilling had been completed at remote mills before shipment to the yard, saved time at the shipyard under the conditions existing during the war.

Another radical suggestion, which was never used to the extent which its merits warranted, was the electric welding of the frames and plates of the hull instead of riveting. Autogenous or fusion welding has been in use for many years. Most of this work has been done by the use of the gas torch, to which oxygen and acetylene are supplied. The weld is formed by fusing together the adjoining edges of the pieces of metal. Material is sometimes added at the same time from a metal rod.

In the electric-arc welding process, the fusion of the metal is effected by an electric arc formed between a metal rod (or electrode) and the pieces to be joined. Metal from the rod is deposited in the weld.

Due to the prohibitive cost of the gases required for oxyacetylene welding, its use upon ship hulls was greatly restricted and the possibility of using electric welding to replace riveting was carefully considered.

The Welding Research Committee of the Emergency Fleet Corporation was formed to study the matter carefully and conduct any needed investigations. This Bureau had representatives on the committee and performed much of the laboratory work for determining the properties of the welds, particularly the strength.

In order to obtain definite information upon welds which were being made commercially, a large number of pieces of one-half inch steel plate were welded at different shops, using all available types of apparatus. These were known as the Wirt–Jones tests and attracted a great deal of attention from engineers and shipbuilders.

The welding data included a mark by which the operator could be identified, the position in which the weld was made, the type of weld, and the rate of welding. The type of electrode used with the diameter and manufacturer, as well as the arc and open-circuit voltage and the amperage, were recorded for each test weld.

These data were obtained in the shops where the welds were made. The specimens were machined there and elsewhere.

The physical tests were all made at the Bureau of Standards and consisted of tensile, torsional, fatigue, and cold-bending tests.

It was found that all of these, except the fatigue tests, which gave erratic results, were consistent. A specimen showing high strength in the tensile test showed high strength in the torsional also. Those specimens showing relatively high ductility in the tensile tests showed equally well in the cold-bend tests. The fatigue tests were made in three Upton-Lewis machines and by three different engineers. Unfortunately, the results do not appear as consistent as could be wished. Many fatigue experiments should be conducted if reliable data are to be obtained upon this important property of welds. It is believed by many engineers that the failure of welds in service is usually by fatigue, and that this property of welds is relatively more important than the fatigue resistance of the material in which the weld is made.

In an extension of the experimental work to determine the fatigue resistance of welded joints such as would be actually used in ship construction large specimens were made from plates one-half inch thick, 8 inches wide, and 40 inches long.

A fatigue machine driven by a 15-horsepower electric motor was designed and built to subject these specimens to repeated bending stresses with provision not only for recording the number of cycles of stress required to cause failure, but also for making an autographic record of the stress produced in the welded material for each application of load.

The total number of specimens in this series was over 200, and the testing work required most of the time of two engineers for nearly a year.

In addition to the Wirt-Jones tests, this Bureau was at one time making progress reports to the welding committee on 14 investigations planned to give information upon some of the many problems constantly arising in connection with welding work. The number of specimens involved in these investigations varied from 5 to 42.

Due to the satisfactory results obtained from these tests, it was decided that the electric-arc welding process was suitable for ship construction, and the committee formally recommended to the Emergency Fleet Corporation that a merchant ship be designed to utilize welding wherever it could be employed to advantage, and that the ship be completed as soon as possible.

The signing of the armistice took place before much progress was made, but some commercial shipyards are now energetically preparing to construct ships in which nearly all the frames and plates for the hull are welded into place.

It is estimated that the cost of welding will approximately equal the cost of riveting plates and frames after they have been "laid off" and the rivet holes punched. For welding, however, all this preliminary work is unnecessary, and the plates and angles do not need to be as accurately cut to dimensions. The saving, if welding is used, is therefore very large and it is chiefly a saving in labor cost, which under present conditions constitutes a large portion of the total cost.

One result of these extensive investigations was the important conclusion that the best physical properties were obtained from those specimens welded with the highest current density in the electrode. Apparently, under this condition, thorough fusion occurred in the weld.

The importance of this discovery, which is generally accepted at present, is very great. The fact that little properly conducted investigational work has been done upon welding processes, and the many possible lines for improvement, leads to the conclusion that such work offers great possibilities if properly carried out.

The American Welding Society, an outgrowth of the welding committee, has been formed to encourage welding-research work by coordinating the efforts of industrial, educational, and governmental laboratories. This Bureau is assisting the work of this society in so far as possible.

Tensiometer.

It is a well-known fact that it is very desirable to know the load that is placed upon the wires and cables of airplanes.

Heretofore no instrument has been available for measuring these stresses with sufficient accuracy. With this purpose in mind an instrument was designed by one of the members of the Bureau's staff and constructed in the Bureau shop. It consists chiefly of two supports at a fixed distance apart and a moving plunger located midway between them, by means of which the wire may be deflected a definite amount of 0.1 inch. The load on the wire is measured by an Ames dial, which measures the compression of a calibrated spring against which the plunger operates.

This instrument, which gives accurate readings on wires of small diameters, requires the use of calibration curves when heavy wire, cable, or stream-line sections are used. Two sizes of this instrument have been supplied at the instance of the Bureau of Construction and Repair, Navy Department, the smaller one being made for wires from 0.05 to 0.25 inch in diameter, and the large one for wires and cables from one-fourth to three-eighths of an inch in diameter. These two sizes of tensiometer were calibrated on 10 sizes of cables ranging from one thirty-second to three-eighths of an inch in diameter; on four sizes of hard-drawn wire and on four sizes of stream-line wire, and were found to give very satisfactory results.

The instrument is sufficiently accurate, being capable of indicating the actual load within 1 per cent of the actual load on the wire, if it is under a load of more than 1,000 pounds. It is simple in construction as well as quickly and easily operated.

Over a hundred of these instruments have been built and are being used by the Navy Department.

Investigation of Wire Rope.

The results of an investigation on 275 wire ropes have been published in Technologic Paper No. 121. The ropes ranged in diameter from one-fourth to 3¼ inches. Five important classes were tested: (1) Very flexible rope of 6 strands, 42 wires each, used for boat tillers and elevator hand lines; (2) ropes for guys of derricks, stacks, and haulage purposes having 6 strands, 7 wires each; (3) (4) transmission rope of plow and crucible cast steel having 6 strands, 19 wires each; (5) extra-flexible plow-steel rope of 8 strands, 19 wires each. The laws of construction and behaviors of the specimens have been reduced to empirical equations. The results of the tests are compared with the strengths called for in well-known specifications.

A further investigation has been carried out to determine the relative strengths of hoisting and transmission wire rope when used in connection with sheaves, as in the case of derricks and cranes. This investigation was made possible through the aid of a large manufacturing corporation supplying the necessary materials. The ropes varied from five-eighths to 1¼ inches in diameter and were tested when bent over sheaves of diameters 10, 14, and 18 inches. An abstract of the results was published in the Engineering and Mining Journal, April 26, 1919. It was shown that the strength on 18-inch sheaves varied from 96 per cent of the strength in direct tension for five-eighths-inch ropes to 87 per cent for the 1¼-inch ropes. The corresponding values for 14-inch sheaves were 95 and 82 per cent, and on 10-inch sheaves 84 and 77 per cent. The mean departures from this range were about 1 per cent. The above values should be reduced about 10 per cent when the strengths are expressed in terms of the aggregate strengths of the wires in a specimen.

The cables generally fractured at the point of tangency with sheaves. Cracks developed in several sheaves, showing that there were opportunities for improvements in design, but as a whole the strength of the sheave system was limited by the individual strengths of the wire rope, which as a function of the diameters was expressed by the formula $S=83{,}000\ d^2$.

Oxyacetylene.

A carefully planned series of tests intended to demonstrate the economy and efficiency of oxyacetylene welding and cutting apparatus is being made. Apparatus from most of the leading manufacturers in this line has been received for test.

The tests are planned to show the conditions under which backfiring occurs, the characteristics of regulators under varying tank pressures, the economy of the apparatus in welding and cutting operations on material of various thickness, and in some measure the durability and the ease with which repairs can be made in service.

Machetes.

A number of machetes, representative of material intended for purchase by the Panama Canal, were submitted for test to determine their suitability for use in cutting and clearing away brush and undergrowth of the Panama Canal district.

These machetes were subjected to a series of mechanical tests, such as Brinell hardness and cold bend, to determine the variations in properties which exist in the commercial product; that is, the hardness along and across the blade and its comparative toughness as indicated by bending. Chemical analysis and micrographic examinations were also made. These tests gave comparisons between various blades of one manufacture, indicating the constancy of his product as well as the difference between blades of different manufacturers.

While certain of the blades submitted proved unsatisfactory, in that they were brittle, most of the others passed all tests and apparently are satisfactory for the work intended, with the exception possibly of the Brinell-hardness number. None of the blades reached the desired hardness number. There was also some variation in carbon content, but the effects of this latter was generally made up by improved heat treatment.

Such tests might well be applied to a large number of cutting instruments.

Brinell Hardness Table.

A Brinell-hardness numeral table, correct generally to the second decimal place, has been compiled and lithographed, which gives the Brinell-hardness numeral for each hundredth of a millimeter of diameter of indentation from 2 to 6.94 millimeters and for pressures of 500 and 3,000 kilograms.

Copies of this table will be sent gratis upon application.

Piston Rods.

A number of tests were made on 8-inch recoil piston rods for 12-inch Barbette carriages at the instance of the Ordnance Department of the Army.

The rods were submitted for a tensile-proof load of twice the working load for the purpose of insuring the quality of the material entering into the forging. All of the rods which were tested in this manner proved entirely satisfactory.

Nonscatterable Glass.

This protective glass, suitable for aviators' goggles and airplane wind shields, consists of a sheet of celluloid "welded" to one side of the glass, the intention being to place the celluloid on the side toward the person to be protected.

An interesting series of tests—that is, firing, to determine the effect of small-arm projectiles; cross bend, loading as a simple beam to determine its strength; and impact, to find the effect produced by the striking of a pendulum weight—were made on this glass to determine its value as a protective screen, and to note the effect the celluloid coating has on the strength of the glass.

In the firing tests it was found that the dangerous scattering of large pieces of glass was entirely prevented. The celluloid coating was easily scratched or marred. In the impact tests the plain glass was broken into many small pieces, while the treated samples cracked, but the pieces were held together by the celluloid. In the cross-bend tests the treated glass of a given kind and thickness was about 15 per cent weaker than the plain glass when the celluloid-coated side was in compression, and about 40 per cent stronger when the celluloid was in tension.

Metal Airplane Construction.

No experimental work has been done during the past year upon the use of metal to replace wood in airplane construction, such as was carried on the previous year by this Bureau in cooperation with the Empire Art Metal Co. and the Airplane Engineering Division of the Bureau of Aircraft Production. Immediate interest in the subject decreased upon the signing of the armistice, but the future of metal construction appears promising, especially as the need for a fire-resisting airplane becomes more generally understood.

To avoid the difficulty which has been found in designing sheet-metal parts so as to secure sufficient compressive strength—as, for example, in the flange of a beam or spar—one engineer has devoted much time and study to the use of steel tubes. A single metal tube has much less strength for its weight than a beam designed to concentrate most of the material in the flanges which are subjected to the higher stresses.

The tubular design uses several small cold-drawn steel tubes for the flanges which are connected by diagonal latticing of tubes of smaller diameter. The design is very flexible in that the number of tubes used may be varied in the length of a single beam to meet the strength requirements. It is also possible to join tubes by inserting a snugly fitting tube of smaller diameter into another for a distance which will give satisfactory strength. Methods of fastening the two tubes together readily present themselves.

It is believed that encouragement and assistance given to metal construction by this Bureau is now about to result in material improvements in that field which will come into general use.

Semisteel Shells.

At the request of the Ordnance Department of the Army, a number of 155-millimeter shells of semisteel have been subjected to a thorough examination as to mechanical, chemical, and metallurgical properties. In order to determine the probable stresses set up in shells that showed excessive expansion after firing, tests were made to determine the true elastic limit; that is, that stress at which permanent deformation is first produced. Further, a study was made of the variation in the chemical and mechanical properties throughout the length of the shell. It was found that the strength of the material, its hardness, and the percentage of combined carbon decreased consistently from the thin section at the nose of the shell to the heavy fuse sections. This agrees with what might be expected from such a material as semisteel, a modified cast iron.

The entire series of tests on semisteel shells also indicate that at present there is considerable variation in the mechanical properties and chemical composition of the so-called semisteel.

Bronze.

Over 300 samples of bronze have been submitted by Division VIII for tests. Among the different varieties were the following:

Cast, both heat-treated and not heat-treated, phosphor, Government, nickel, and welded bronze.

Tensile tests were made on these specimens in order to determine their proportional limit, ultimate strength, elongation, reduction of area, and modulus of elasticity. Stress diagrams were drawn for each specimen.

Calibration of Testing Machines.

During the past year considerable work has been done upon the calibration of testing machines.

Four testing machines having a capacity of 200, 4,000, 80,000, and 150,000 pounds, respectively, and one having a capacity of 100,000 pounds, were tested at the navy yard, Washington, D. C., by means of the Emery proving levers.

Other machines and instruments calibrated by this section are the following: Dynamometers, both tractor and recording; tension meter (Crowell); tensiometer (Larson); horizontal Scott testing machine; 10,000 and 50,000 pound Riehle testing machines; 20,000-pound Olsen testing machines; 2 and 8 inch Berry strain gauges; Olsen McAdam impact-testing machines; Upton-Lewis testing machines.

Circulars of Information.

The following is a brief summary of a few of the letter circulars prepared by Division VII-1.

Letter Circular VII-1-1, "Mechanical Properties of Materials." A great deal of time was spent in the preparation of this most valuable and interesting paper, which contains the best available data on the strengths and related properties of metals, alloys, and certain nonferrous materials. Among the materials treated are iron, carbon steels, alloy steels; wire and wire rope; semisteel; aluminum, copper, and miscellaneous metals and their alloys; rope, rubber, leather, and wood. This circular also includes definitions of the properties treated and references to sources. These data were originally compiled for the Smithsonian Physical Tables, from technical literature, the Bureau's test reports, and other reliable sources.

There has been such a great demand for this paper that it has been prepared for publication as a Bureau circular.

Letter Circular VII-1-2, "Definitions of Mechanical Properties." This gives definitions which govern the more commonly confused terms for properties determined from mechanical tests of materials shown in the tables of Letter Circular VII-1-1, such as P-limit, elastic limit, yield point, ultimate strength, modulus of rupture, modulus of elasticity, Brinell-hardness numeral, Shore scleroscope hardness, and Erichsen value.

Letter Circular VII–1–4, "Standard Test Specimens for Mechanical Properties of Metals." This circular gives a detailed description and a dimensioned drawing of the specimens to be submitted for the determination of different mechanical properties, such as tension, compression, torsion, fatigue, or impact strength.

Letter Circular VII–1–5, "Fees for Mechanical Tests." This circular gives the fees charged by this Bureau for conducting tests for the determination of mechanical properties, such as those mentioned in Letter Circular VII–1–4 above.

Letter Circular VII–1–6, "Parker Variable-Camber Wing." This gives a very good description of a new type of airplane rib recently designed and built at this Bureau, including tables of test results on same.

These circulars have been prepared in mimeographed form, and copies will be sent gratis upon application.

Publications.

The following is a brief outline of the publications which were prepared by this section:

Physical Properties of Materials, by H. A. Anderson, assistant engineer physicist: A compilation from the best available sources of data on the various physical properties of metals and other nonferrous materials, with definitions of the properties treated and references to sources.

Test of 150-Ton Floating Crane, by Louis J. Larson and Richard L. Templin, assistant engineer physicists: A description of the methods employed, with analysis and discussion of the results obtained from the strain-gauge measurements taken on many different portions of the crane.

Strength of Spruce Struts, by Prof. James E. Boyd: Experimental data on the strength of spruce airplane struts of uniform cross section, together with the development of the mathematical theory for the design of plain and tapered struts.

The following papers will soon be in the hands of the Publication Committee, as the manuscript is practically complete at this time:

Physical Tests of Motor-Truck Wheels, by Charles P. Hoffman, assistant engineer physicist: Experimental data on radial compression and skid tests of cast-steel, pressed-steel, wrought-iron, and wood wheels.

Strain-Gauge Measurements on the Arlington Building, by Louis J. Larson: Strain-gauge measurements and analysis of the strength and the theory of design of the so-called Schuyster system of fireproof building construction.

Moving Laboratory to New Quarters in Industrial Building.

During the late winter and early spring, the office and laboratory of this section have been moved to new quarters in the industrial building. To date most of the moving has been completed. There still remain, however, the two Emery machines in the west building and the equipment in the Pittsburgh laboratory to be installed in the new location. These latter need special consideration. All equipment now installed in the industrial-building laboratory was moved under the direction of the section chief. In reinstalling the machines especial care has been taken to so place them as to afford maximum lighting and working space. Further, each machine is being overhauled and readjustments or repairs made wherever needed. This latter was rendered necessary by the strenuous use with minimum repairs of the entire equipment during the period of war.

Summary of Tests Made by Engineering Materials Section.

The following statement shows various materials tested by this section during the fiscal year ending June 30, 1919, together with the number of specimens of each type:

Tests of metals.

	Specimens.
Iron and steel:	
Carbon steel	263
Cast iron	9
Malleable iron	6
Nickel chrome steel	2
Semisteel bars	3
Strap iron	4
Welded bars and plates	150
Total	437
Aluminum and aluminum alloys:	
Aluminum alloys	252
Aluminum, chemically pure	42
Aluminum solder	6
Total	300
Copper, brass, and bronze:	
Bronze, nickel	2
Bronze, phosphorus	7
Bronze, various	358
Copper	5
Total	372
Miscellaneous metals and alloys:	
Alloy, lead antimony	19
Alloy, resistant metal	5
Babbitt metal	8
Bearing metal	19
Dental amalgam	65
Nickel	8
Tensilite	1
Total	125

Tests of wood.

Various species:	
Cypress	56
Various	50
Total	106

Tests of fiber rope, wire rope, and chain.

Chain:	
Sash chain	1
Various	149
Total	150

Wire, wire rope, and cables:	
Cables, various	39
Wire, shot-line	10
Total	49
Fiber rope (manila, sisal, etc.): Various	66

Tests of other material.

Bakelite type insulating material	417
Celluloid	4
China plates	42
Disks, round	4
Sapphire balls, bearings for instruments	12
Shellac composition	12
Total	491

Calibration of machines and instruments.

Berry stain gauge	2
Brinell Hardness specimens	95
Calibration specimens	110
Dynamometers	4
Horizontal Scott testing machine	2
Larson tensiometer	9
Lewis-Hayes extensometer	1
Olsen testing machine	1
Riehle Bros. testing machine	2
Standard scale spring	1
Upton-Lewis repeated stress springs	13
Total	240

Tests of fabricated parts.

Airplanes and airplane parts:	
Beams or spars	23
Cables	1
Alloy steel bolts	6
Gunners' belts	37
Parachute rings	7
Pilots' belts	10
Ribs	2
Straps	12
Struts	37
Wings, veneered	10
Total	145
Wheels:	
Artillery	6
Steering wheels	18
	24
Guns, shells, powder containers, etc.:	
Ammunition packing cases	101
Adapters and booster casings	63
Fuses, nose	3
Gas shells	5
Grenades, hand	1
Gun mount	33
Gun shells	64

Guns, shells, powder containers, etc.—Continued.	
Gun steel	27
Mechanism cases	2
Powder containers	2
Projectors, steel shell	3
Rifle barrels	10
Roller bearings	9
Shell cases	4
Shrapnel fragments	2
Swivels, Browning gun	9
Total	338
Miscellaneous:	
Abercrombie seal	7
Acme sealing device	7
Alloy steel bolts	14
Armor mesh	2
Armor plate	26
Ball bearings	15
Brass tubing	2
Canvas covers	8
Cinchas	3
Cleavers, butcher's	8
Condenser tubes	4
Cord, exerciser	2
Electrodes	20
Hammers, steel handles	4
Handles, rope	8
Flexible contact for searchlights	6
Jacks	9
Lock nuts and bolts	5
Machetes	15
Pick mattocks	2
Piston rings and rods	8
Reinforcing bars	58
Rings and staples	36
Rings, locomotive packing	20
Scythe blades	2
Seals, metal	6
Shield and wire cutter for tank	1
Springs	34
Steel fence posts	8
Steel tubing	38
Pulleys	12
Nickel joints	4
Turbine	1
Welded specimens	242
Wire-link fabric	2
	539
Grand total	3,382

Equipment.

A new apparatus for testing full-length airplane beams has been designed and installed in the laboratory. This apparatus is so built that the airplane beams may be tested under the combinations of loadings (rib loads, pull from guy wires, and thrusts from struts) actually acting on a beam when installed in an airplane.

A 10,000-pound repeated bending testing machine capable of taking specimens 30 inches long and 12 inches wide has been designed and constructed. The machine was originally developed to study the fatigue-resisting properties of electrically welded ship plate.

The great need for an accurate device for the calibration of testing machines has led to the design of a dead-weight calibrating machine that would permit of calibrating testing machines by a standard calibration bar. The present maximum capacity of the machine is 100,000 pounds. While the machine as constructed is not considered ideal, it will, it is believed, be more accurate than anything now used for calibration purposes. The machine has been constructed and is now awaiting assembly and adjustment. In conjunction with this machine, it is proposed to use a standard calibration bar having a 15-inch gauge length and suitably formed ends. This calibration bar of heat-treated nickel steel will be loaded with standard deadweights and its deformation accurately measured. Observations on the deformation of the same bar in testing machines will allow their accuracy to be determined.

A new 50,000-pound capacity, high-standard, Universal testing machine, manufactured by the Tinius Olsen Testing Machine Co. and capable of taking tension or compression specimens 8 feet long, has been installed in the laboratory.

A Brinell hardness testing machine, a gift from the United States Army, and manufactured by the Scientific Instruments Co., of Pittsburgh, has been added to the equipment.

The laboratory equipment has been further augmented by the addition of several extensometers of the Bureau's design, a new recording scleroscope, and a Leeds & Northrup indicating pyrometer.

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.)

The beginning of the year found the work of this section greatly congested, with practically all of its facilities devoted to war service. The testing and inspection of cement for the Government departments had increased to such proportions that the extension of facilities for this work during the latter part of the preceding fiscal year required still further enlargement, and the normal investigation work had almost wholly given place to emergency research and testing required by the Army, Navy, and by the Shipping Board. Following the signing of the armistice, cement shipments and the corresponding amount of testing fell off markedly, while the military research work diminished more gradually. In the latter part of the year a portion of the prewar investigative work was resumed, but a considerable amount of work initiated by war problems was continued throughout the year and will need to be kept up in the future.

At the close of the year the most serious problem confronting the section was the maintenance of its organization of branch laboratories, two of these (at Denver and San Francisco) having been transferred the year before from the Reclamation Service. These two laboratories should be continued for the very valuable service they are capable of rendering in the West, not only in connection with the inspection and testing of cement and other structural materials but particularly to meet the needs of reclamation and highway work.

New Branch Laboratories.

The construction of the large Army and Navy supply bases at Brooklyn in the latter half of the calendar year 1918 required nearly 900,000 barrels of cement. This was largely drawn from the mills in the Hudson River district, and in order to meet the testing and inspection requirements of these and other projects, a fully equipped cement-testing laboratory was established at Hudson, N. Y. This laboratory was in operation nearly four months, from August to November, inclusive, 1918. The work in this district was thereafter handled by resident inspectors, the tests being made at the Northampton (Pa.) laboratory in the Lehigh district.

It also seemed desirable to increase the Bureau's testing and investigating facilities on the Pacific coast. After considering the needs of the Army and Navy and the Emergency Fleet Corporation at Los Angeles and San Diego, a very convenient laboratory for chemical and physical work was installed in one of the more permanent exposition buildings at San Diego, where tests of cement, aggregates, and sands, iron, steel, etc., have been in progress since last November. This laboratory has been especially helpful in the construction of concrete ships, and to both the Army and Navy in their construction of aviation fields on North Island. Owing to lack of funds for its further maintenance, this branch will be discontinued July 31, 1919.

On account of the concentration of testing work in the Lehigh district, a well-equipped chemical laboratory was established at Northampton, Pa., to eliminate the delay arising from sending chemical samples to Washington or Pittsburgh. Since the amount of cement tested and inspected in the Lehigh district is always relatively greater than in the other cement-producing districts, this chemical laboratory should be permanently retained.

Routine Inspection and Testing of Cement.

Shipments of certified cement for Government construction work during the fiscal year were by far the largest in the history of the Bureau. The total shipments for the year amounted to more than 6,500,000 barrels, of which the total cost to the Government was approximately $160,000, or slightly less than 2½ cents per barrel. It may be noted that the cost of this work necessarily included the cost of a large part of the equipment required by the branch laboratories, as well as the actual cost of inspection and tests. It is further interesting to note that the cost of this work alone considerably exceeded the entire appropriation for testing structural materials, only a small portion of which can be allotted to the testing of cement. While the inspection and testing of cement during the next fiscal year for the Government departments is estimated to be only about 35 per cent of the amount required in 1919, it is imperative that the work be provided for by direct appropriation. The reimbursement plan which has been followed as a war measure has proven to be impracticable, and while it will be again necessary to start the new year's work on this basis, it can not be so continued indefinitely. Too much emphasis can not be placed upon the recommendation that the work be adequately provided for, or else abandoned entirely.

The following statement of the quantities of Government-purchased cement certified by the Bureau during the past three years shows clearly how the war affected this part of the work of the structural materials division.

Month.	Shipments of tested cement in barrels.			Month.	Shipments of tested cement in barrels.		
	1916–17	1917–18	1918–19		1916–17	1917–18	1918–19
July	36,568	81,364	1,121,960	March	54,525	335,999	311,210
August	14,941	102,259	1,053,167	April	48,718	605,128	280,229
September	58,765	146,249	1,053,998	May	64,325	768,395	255,646
October	32,150	32,366	948,937	June	76,646	752,161	227,857
November	27,388	205,959	719,711				
December	16,012	183,406	247,137	Total	502,845	3,597,354	6,588,923
January	29,063	113,104	186,806	Rejected cement[a]	72,000	331,000	742,000
February	43,744	270,964	182,265				

[a] The total amount of rejected cement in 1917–18 and 1918–19 was greater than indicated in the table. This is due to the fact that records were not available from two commercial labortories acting for and under supervision of the Bureau in the Middle West and southeastern districts.

The greater part of the cement shipped during the past fiscal year was used on rush work of a military character, such as terminals, forts, factories, shipyards, dry docks, roadways, and bridges. In addition, a considerable quantity of specially ground cement was tested for the concrete ships built under the supervision of the Shipping Board.

Inspection was made at mills in 25 States, as follows: Alabama, California, Colorado, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Montana, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Utah, Virginia, Washington, and West Virginia.

Development of Testing Methods.

During the latter half of the year some progress has been made in systematizing and improving the methods of proportioning materials employed in the laboratory for fabrication of test pieces of mortar and concrete, which it is believed will aid in obtaining more accurate and uniform test results. A study has also been made of the effect of variations in the storage and curing of test pieces. A new method has been devised of measuring the "consistency" or "flowability" of concrete, these terms referring to the somewhat indefinite, but very important, property of concrete mixtures which is primarily dependent upon the amount of water used in mixing.

Methods of Proportioning.—Although in the field concrete materials are proportioned by volume, it is essential in the laboratory that weight per cubic foot be known to insure accuracy in duplicating tests and eliminating a variable which may obscure the real differences in strength which should be obtained when comparing different aggregates or in repeating tests with the same aggregate. Often weights are reported as loose weights, determined by allowing the material to fall into the measuring vessel without jarring or tamping. In other cases weights may be reported as packed or tamped weights. The method now employed in the laboratory is to fill the vessel one-fourth of the height and shake and bump until no reduction in volume is apparent, repeating until the vessel is full. The top is then leveled with a straightedge and the net weight determined. The weight used in proportioning and in reporting the result of this test is 95 per cent of the packed weight so determined. Many tests have shown this 95 per cent packed weight to be approximately the average of the loose and packed weights. Since the weight of 94 pounds per cubic foot assumed for cement is approximately an average weight of cement loose and packed, the volume proportions used in laboratory tests are true volume proportions.

Storage and Curing of Test Pieces.—In connection with tests of concrete aggregates, observations have been made of the effect of storage and curing conditions on the compressive strength of concrete up to 28 days. Test pieces molded from the same batches of concrete, in every way comparable, were stored in water, in damp sand, and in a damp closet. In general, it may be stated that under properly controlled conditions these methods are equally satisfactory.

The results obtained varied so slightly that for any one concrete the results of all test pieces could properly be averaged. Temperature conditions under all three methods were practically the same, so that with this sometimes variable factor eliminated it may be stated that any method of curing is efficient which permits all water to be retained in the specimen and permits no evaporation to take place. In a humid atmosphere, such as the damp closet, a sprinkling once daily apparently permitted no essential loss of moisture from the mass. This condition should be especially reassuring and satisfactory to drain tile and other cement-product manufacturers, since it shows that closed rooms kept moist by occasional sprinkling during the curing period, furnish efficient means of storing these products. It should not be assumed from this that additional benefit will not be derived from a well planned and operated system of steam curing.

Flowability of Concrete.—Work which has been done in the laboratory in connection with tests of methods of proportioning concrete mixtures emphasizes most strongly the importance of being able to measure and express the important and fundamental quality of flowability of concrete. In actual work some minimum flowability must be attained, and laboratory concretes should be made with this requirement in mind, since on the job, if the concrete does not have sufficient flowability, more mixing water will be added. Such a property and condition is a necessity, but it is well known that increase in water lowers strength. Therefore, it is essential that aggregates tested in the laboratory should be tested in concretes having the same conditions of flow. Otherwise, misleading and incorrect conclusions will be drawn as to their relative values for concrete making.

In the last annual report a method for determining the consistency or flowability of concrete in the field was described. The apparatus consisted of a piece of cylindrical tubing 6 inches in diameter by 12 inches high, which was filled with freshly-mixed concrete and then withdrawn vertically from the mass. The amount of settling of the unsupported concrete depended upon the amount of water used, and was, therefore, a measure of consistency. This test, commonly known as the "slump" test, was fairly well adapted to the rich mixture employed in ship and highway construction, but was found to be unsuited to the leaner and widely varying types of concrete which are encountered in the testing laboratory.

The flowability is now measured by molding a mass of concrete on a metal-covered table whose top can be raised a fixed height by means of a cam and dropped. The resulting bump will cause the concrete to spread in circular form, concentric with its original outline, the increase in diameter after a given number of repetitions of the bump being a measure of its flowability. Tests to determine the best form of test piece, as well as the height and number of drops, are still under way, but a number of interesting facts are already apparent. It is found that whatever the proportion of cement to aggregate, whether a 1—1—2 mix or a 1—3—6 mix, increase in flowability is proportional to increase in percentage of mixing water. Definite figures for flow can be obtained for concretes too dry for any ordinary practical purpose and also for concretes so wet that they would be ruled off of any properly inspected work. This variation in flow with increase in percentage of mixing water is essentially a straight-line relation within the limit of practical working mixes.

Some work has also been done with an apparatus of this type in determining the consistency of cement pastes, which is a fundamental step in the ordinary testing of Portland cement. While a comprehensive program of experiments has not yet been carried out, it may be stated that the method promises to be of higher merit than either the Vicat or ball methods now prescribed in the specifications.

Design of Concrete Mixtures.

During the past year two new theories of proportioning concrete aggregates have been advanced. One of these theories is based on the assumption that the ratio of the volume of mixing water to the volume of cement in a concrete mixture determines the strength; that the grading of the aggregate is important only in so far as it affects the amount of mixing water; and that aggregates having the same "fineness modulus" (which may be regarded as a measure of the average or effective fineness), even though differing widely in gradation of sizes of particles, will produce concretes requiring the same amount of mixing water, and consequently having the same consistency and the same strength. The second theory is based on the assumption that if the amounts of both cement and water in concrete mixtures are properly proportioned to the total surface areas of the aggregates, concretes of the same consistency and strength will be obtained.

A considerable amount of work has been done by the Bureau in checking the validity of these theories, particularly in so far as they relate to the predetermination of the strength of concrete. In the studies which have been made thus far it has been established (1) that slight variations in the amount of mixing water have a relatively large effect on the flowability and strength of concrete; (2) that the amount of water required in a concrete mixture must from practical considerations be based on a definite degree of flowability; (3) that the amount of water required in a concrete mixture can not be determined by the formulas accompanying the theories referred to, nor at the present time by any known method other than by trial with a suitable apparatus for measuring the flowability of a concrete mixture. A great deal of effort has therefore been devoted to the development of an apparatus of this kind, which has been described in some detail in a preceding paragraph. By means of this apparatus it has been demonstrated that the water required to gauge a concrete to a definite degree of flowability unquestionably depends upon the surface area of the aggregate, regardless of its fineness modulus; to precisely what extent this and other factors enter has not yet been determined.

A discussion of the results of this investigation has been published in the technical press and reported to the American Society for Testing Materials.

Fineness Investigation.

Under this heading may be included the determination of the properties of finely ground cements, the determination of the gradation of finely divided materials by means of the air analyzer, the standardization of testing sieves, and the preparation of standard cement samples.

Higher Strength from Finely Ground Cements.—On behalf of the cement committee of the American Society for Testing Materials, a considerable amount of time has been given to the tabulation of existing data on the increased strength obtained in concrete from the use of more finely ground cements. An attempt also has been made to obtain data on the costs of finer grinding, with a view to determining, if possible, whether a further increase in the fineness requirement of the standard specifications is warranted. So far as increased strength is concerned, the fairly definite conclusion has been reached that 1 per cent increase in fineness yields very approximately the same increase in strength as an addition of 1 per cent in the quantity of normally ground cement. The cost data are inconclusive, not only because the estimates obtained differed widely, but mainly because so many factors have to be considered in determining the value of the estimates. It may be stated, however, that the majority of the figures submitted were based on loss of production occasioned by finer grinding, assuming the mills to be operating at full normal capacity. Taking the figures at their face value, the average increase in cost to the consumer appears to be nearly the same, whether he pays the higher price for finer cement or the increased cost of a larger quantity of normally ground cement.

An opportunity was obtained during the year to make tests of an unusually fine cement put upon the market by a progressive manufacturer. The increase in strength obtained in comparison with the normally ground cement was marked, and it was readily demonstrated in this particular case that the intelligent user could save money and get a better product by using the finer cement. The investigative value of these tests, however, lay chiefly in the fact that general results differing from those of similar tests in the past were obtained; for example, a very great gain in strength of the richer mixtures, but a less marked increase in the leaner mixtures. It is not known whether this reversal is a peculiarity of the material or whether in the decision to base all concrete tests upon accurately controlled field consistencies the results obtained were characteristic of the wetter mixtures. The entire series with this and other cements of high fineness will be repeated.

Air analyzer.—Throughout the period of the war pressure of other work prevented further development or improvement of the air analyzer. This apparatus is used for the mechanical analysis or size gradation of finely divided materials. During the past year it has been used in the mechanical analyses of various materials under investigation by the Bureau, particularly normal cements, blended and reground cements, and cements ground by a new type of mill. It is believed that the air analyzer may be adopted for mechanical analyses of other materials than cement, as clays, mineral powders, abrasives, pigments, explosives, etc. It is hoped that original research for the wider use and development of the air analyzer may be resumed at an early date.

Standard Cement Sieves.—During the year 56 200-mesh sieves were standardized. In the annual report for 1918 it was indicated that it had become difficult to obtain 200-mesh sieves that would meet the Bureau of Standards' specifications. During the present year there has been a decided improvement in the quality of sieves submitted to the Bureau for standardization. When the war came on the American manufacturers were cut off from the their European sources of supplies of 200-mesh cloth and manufacture of the latter was taken up in America. The American cloth was made of somewhat different material from that obtained in Europe and presented new problems and difficulties in weaving. Apparently these difficulties are being or have been overcome, and it is now possible to obtain sieves meeting the specifications of the Bureau.

Standard Fineness Samples.—The Bureau continues to issue standard fineness samples of cement for checking up 200-mesh sieves. These are supplied in two degrees of fineness, 46–e, 80.2 per cent passing the standard No. 200 sieve, and 47–b, 88 per cent passing the standard No. 200 sieve. These samples are issued in sealed glass jars, each containing about 160 grams of cement. Each sample is accompanied by full directions for its use. With these samples, 200-mesh sieves may be compared with the fundamental standards and correction factors obtained. During the year 134 samples were issued to owners of No. 200 mesh sieves, a nominal price being charged for each sample. There has been an increased demand since the end of the war, 110 of the above samples having been issued since January 1, 1919. About 150 of these samples were used by the Bureau in standardizing sieves submitted, and checking up its own 200-mesh sieves.

Volume Changes in Mortars and Concretes.

The study of volumetric changes in mortars and concretes was largely set aside during the war, and the present program was undertaken only at the beginning of the calendar year. The work has been confined entirely to the laboratory, and special stress has been placed on determining the volumetric changes that take place in mortars during and following the time of setting. Up to date the Bureau has dealt mainly with volumetric changes in 1-to-3 and 1-to-4 mortars and other typical stucco mixtures. Early in the work considerable study was made of the methods and apparatus for determining the volumetric changes, and it is gratifying to state that the Bureau has been able thereby to get accurate and consistent results. Although over 50 specimens have been made up and placed under test, it is yet too early to draw any definite conclusions, since observations are still being continued on most of them.

It is the purpose of these investigations to determine, first, the exact amount of volumetric change in the various materials; second, the causes of these changes; and, third, a remedy or way of offsetting these changes without losing any of the intrinsic and necessary value of the material. The extreme importance of these investigations has been brought out even in our preliminary tests, as several mixes have shown such serious cases of contraction that would seemingly prohibit their use as structural materials in their present form. As soon as tests are comprehensive enough it is the intention to make a published report of results.

Concrete Oil Storage.

During the past year three main series of tests have been conducted to determine the limitations of untreated concrete tanks for the purpose of storing oils.

Series I consists of eighteen 1:2:4 concrete tanks in which were stored 11 mineral oils with gravities varying from 0.742 to 0.959—that is, from commercial motor gasoline to a very viscous residuum oil—5 vegetable oils, and 2 animal oils. In each tank were placed three 6 by 12 inch concrete cylinders, to be broken after an exposure to the various oils. This series was started to determine the volumetric loss of oil due to absorption and penetration of the oils, but it was found that the physical properties of the oils and the temperature changes played such an important part in determining accurately the loss that these tanks were kept under test as qualitative rather than quantitative tests.

After a year's exposure to the various oils, the concrete of the tanks and cylinders is apparently unaffected, with but two exceptions. The surfaces of the tanks containing cocoanut and lard oils have been attacked and are considerably roughened. The cocoanut oil was more active than the lard oil, but neither has affected the concrete to a greater depth than one thirty-second of an inch, and the penetration observed when the cylinders were broken was 0.2 inch in both cases. The breaking strength of the 6 by 12 inch cylinders showed only a slight decrease when compared with the strength of cylinders stored in air.

Series II and III consist of quantitative and qualitative tests on $1:\frac{2}{3}:1\frac{1}{3}$ concrete tanks, in which the maximum-sized aggregate is one-half inch. The tanks of Series II are under no head, while those of Series III are under a 25-foot head of oil. The oils used in these tests were vegetable and mineral oils, the latter having gravities varying from 0.649 to 0.970; that is, from very light gasoline to a heavy residuum oil. It was found the losses were greater the lower the specific gravity; that where the specific gravity was 0.875 or higher the losses were very small. The head of oil had relatively little effect on the rate of loss.

In the tanks of Series I and II that contained boiled and raw linseed oils a very noticeable deposit of lime soap was observed. This was more marked in the case of the boiled than in that of the raw oil.

Additional experiments are being started along the same line on $1:1\frac{1}{2}:3$ tanks preparatory to taking up the question of oil-proof coatings to determine their relative worth for treating concrete tanks for storing the lighter oils, for it is evident from the results obtained thus far from the tests that concrete tanks properly constructed are practically impervious to oils with gravities of 0.875 (30° B.) or heavier.

Waterproofing Concrete.

Although hampered by a very large amount of war work, the Bureau endeavored to carry out a waterproofing test which had been on its program since 1916. This test called for the construction of three concrete tanks below water level near the Potomac River, the tanks to be built by a local contractor under supervision of a representative of the Bureau. The tanks were to be constructed of 1:2:4, 1:2½:5, and 1:3:6 concretes, respectively, each with 8-inch walls and bottom, 5 feet square, and 10 feet deep, built in a pit, to be kept dry during the work and for a period of two weeks thereafter. The forms were then to be stripped, the pit allowed to fill by seepage, and the water-tightness of the tanks to be determined. This program was carried out in October, 1918, and all three tanks failed in the test. This result was practically assured as soon as the forms were removed, for the concrete had not filled properly around the reinforcement near the bottom, and pockets of considerable size were left near the junction of walls and bottom in all the tanks. For this reason, the test did not serve its intended purpose, which was to demonstrate whether any of the three mixtures would make a waterproof job without the use of integral waterproofing.

An experiment of this kind focuses attention upon the difference between laboratory and field tests of a material such as integral waterproofing. In the laboratory it may be assumed that workmanship is perfect, and the actual merit of the material can be determined by comparative tests of treated and untreated concrete. Quantitative experiments of this type should furnish valuable information, and such experiments will be carried along in connection with the laboratory work of the concrete oil storage investigation, in which the nature of the tests, equipment required, etc., are exactly the same. In the field, workmanship is an uncontrolled variable, which, if it could be measured, might be expressed as a definite fraction or percentage of perfect workmanship. The field test is, therefore, one of waterproofing versus workmanship, of which the results must be inconclusive. To what extent the use of waterproofing compensates for poor workmanship can be determined only to the degree that the latter is capable of measurement.

Stucco.

The work of this investigation has been confined to the application of experimental stuccos to three penthouses on one of the new laboratory buildings of the Bureau. Two of these were coated with 1:4 and 1:6 mixtures of cement and crushed gravel screenings, respectively; the third was an experiment with exposed aggregate finish in which aggregate up to one-fourth of an inch in size was used. All of these were very successful and, in comparison with the richer mixtures commonly specified, are a distinct advance. During the year a recommended practice for Portland-cement stucco has been prepared by the committee on treatment of concrete surfaces of the American Concrete Institute, in which the results of the Bureau's investigation have been embodied.

Durability of Concrete in Alkali Soils and Waters.

This investigation has been suspended since 1916 owing to press of war work. Plans have been completed to resume the field work in the fall of 1919, which will include tests of drain tile previously placed in the alkaline soils of the western United States as well as inspection of test blocks and various concrete structures. The advisory committee which has been assisting in formulating the program of tests, as well as in the conduction of the field work, has been increased by the appointment of members to represent the American Concrete Pipe Association, the Portland Cement Association, and the Engineering Institute of Canada. Cement drain tile for replacement in the drains in 1919 have been made at a factory in Muscatine, Iowa, under the supervision of the American Concrete Pipe Association.

New Material for Increasing Rate of Hardening of Cement.

Considerable work has recently been done on "Cal," which is a new material for increasing the rate of hardening of cement mixtures. It is essentially an oxychloride of calcium in the form of a dry, white powder. It is not delequescent, as is calcium chloride, and can be packed in bags and handled in much the same manner as hydrated lime. "Cal" is added to the concrete materials at the time of mixing, and is quickly decomposed by the water into calcium chloride and calcium hydrate, the calcium chloride going into solution, while the calcium hydrate largely remains in a solid, but very finely divided, form. Thus, the beneficial effects of calcium chloride as to workability and increased rate of hardening of the concrete are obtained, together with the probable effects of calcium hydrate as to increased workability and decreased permeability.

The greater part of this work up to the present time consists of compression tests on 2-inch mortar cubes. These tests indicate that different brands of cement respond to the action of "Cal" to a greater extent than others. The brand least affected gave a strength in $3\frac{1}{2}$ days equal to the 7-day strength of the untreated mortar, the treated mortar containing an amount of the material equal to 5.5 per cent of the cement. The brand most affected by the same treatment gave a strength in less than 2 days equal to the 7-day strength of the untreated mortar. The above results were obtained on test pieces stored in water. Test pieces stored in the laboratory air gave much more favorable results, the treated mortar giving a strength in about 2 days equal to that of the untreated mortar at 28 days. This indicates that "Cal" would be very effective in concrete construction exposed in any way to the drying-out action of the air or sun, and in places where it is difficult or impracticable to keep the concrete continually wet during its early hardening.

The investigation is being continued with concrete, using various mixes and 6 by 12 inch cylinder test pieces. Corrosion tests have also been started. Sufficient data have not been obtained from these tests to make any conclusions possible.

Acceleration of Hardening of Concrete by Steam.

Experiments were made to determine how strong a 1:2:4 concrete could be produced in 48 hours, using steam applied internally and externally to the mass of concrete. These tests were made at the request of the Inventions Section Army War College. Twelve-inch cubes of concrete were subjected to the following methods of curing: Indoor air, external steam, steam flowing through embedded, perforated pipes, steam flowing through nonperforated pipes. Use of perforated pipes proved impractical, due to clogging of the pipes. All three methods of steam curing gave practically the same strength at the end of 48 hours. This strength was from 200 to 400 per cent of the strength of air-cured concrete of the same age, depending upon whether cured indoors or outdoors, and was about equal to the strength of air-cured concrete seven days old.

Automatic Freezing and Thawing Apparatus.

This apparatus, designed for the purpose of making extensive weathering tests on building stones, concrete, bricks, etc., has been experimented with to a considerable extent during the latter part of the year. Forty-eight freezings and thawings can be made in one day, but owing to difficuties experienced in keeping the specimens damp the frost action is not as rapid as desired. Some changes are being made in the apparatus in order to overcome this difficulty.

Investigation of Building Stones.

Extensive tests are being made on Indiana limestone to establish data for a more definite grading of the material and to determine the relative value of the different grades. Tests have been made on 72 samples of the material. Some work has been done on granite in connection with the cooperative investigation of building stones. Tests were made on several samples of quartzite, in cooperation with the United States Geological Survey, to determine its suitability for use in nitro-acid towers. Some time has been given to the study of the thermal expansion of marble for diurnal temperature changes. The results indicate that there is a slight permanent increase in dimensions of newly quarried marble when subjected to the weather. A report of the Bureau's work on the commercial marbles of the United States has been issued as Technologic Paper No. 123.

Service Tests on Floors and Concrete-Floor Treatments.

Several rooms in the Bureau's buildings have been surfaced with congoleum and mastic flooring, giving a variety of service conditions on these materials. These materials are being studied under the various conditions of use.

Numerous inquiries have been received during the past year concerning the value of different treatments for concrete-floor surfaces to prevent dusting. In order to secure reliable information on this subject, an investigation has been started which consists of service tests on a number of floor panels treated with different materials. These panels are being carefully noted at intervals and compared with sections which were left untreated. The treatments under test may be classified as follows: Magnesium fluosilicates, paints and varnishes, waxes, and miscellaneous treatments, such as soap, linseed oil, sodium silicate, and alum. The majority of the treatments have been beneficial, the fluosilicates and sodium silicate being perhaps worthy of special mention. All paints and varnishes have been satisfactory and require longer exposure to traffic to demonstrate their relative durability.

Reinforced-Concrete Investigations.

A large portion of the investigational work in reinforced concrete has been carried out for the Concrete-Ship Section of the Emergency Fleet Corporation under the direction of a member of the Bureau's scientific staff. Details of this investigational work are given in the following paragraphs. A paper giving a summary of the most important of this work was presented at the annual meeting of the American Concrete Institute, June, 1919.

Corrosion Tests of Reinforcing Steel.—The corrosion tests were made to obtain information relative to the importance of corrosion of the reinforcement in concrete ships and to methods of preventing or mitigating corrosion of the reinforcement. About 20 proprietary coatings, including paints and asphalts, were used as protective coatings, and salt-spray tests were made to determine their effectiveness. Many of the coatings were found to be effective in preventing corrosion, but to have serious effect in reducing the bond strength of steel when embedded in concrete.

Bond Tests.—Pull-out tests of specimens, consisting of steel bars coated with the protective coatings previously referred to, were made on about 400 specimens. These tests showed that practically all coatings, even including metallic coatings such as zinc, had a deleterious effect on the bond strength (the resistance to slipping through the concrete) of bars embedded in concrete.

Repeated Reversal of Load on Reinforced-Concrete Beams.—The tests reported in the Annual Report for 1918 on double-reinforced-concrete beams loaded in alternate directions have been carried further. Four beams have been tested to failure, and in all cases failure was by tension in the steel. One beam which has had 2,000,000 applications of the design load shows no indication of the approach of failure. In one beam there was a large amount of slip of a reinforcing bar before failure occurred. Within the limit of these tests there is no indication that the strength of a doubly reinforced-concrete beam (reinforced for bending in opposite directions) is determined by the properties of the concrete, if the ordinary requirements of design are met, unless it be that of the bond stress. The abrasion of the concrete at the edges of cracks in reinforced-concrete ships was considered as a possible danger, and the tests were initiated to obtain information on this subject. There is no indication that this is a real danger. Not all the tests originally planned have been completed. The danger of slipping of bars either where they are lapped at the center of the span or where at the end of the beam they do not have anchorage by hooking of the bars is one which should be investigated and on which certain of the tests already planned should give information.

Impact Tests on Concrete Slabs and Built-up Steel Plates.—In an effort to secure a basis for comparison of resistance of concrete slabs and steel slabs to impact, tests were made in which the impact was furnished by dropping a 1-ton ball upon the center of the slab. Eight reinforced-concrete slabs and one steel slab designed to represent conditions for the shells of reinforced-concrete ships and of steel ships, respectively, were tested. Six of the reinforced-concrete slabs were 6 feet 6 inches by 7 feet in size, and two of them were 10 by 10 feet. The steel slab was 12 by 10 feet 2 inches in size.

Leakage of Water Through Cracks in Reinforced-Concrete Shell.—Early in the investigation of shearing strength of reinforced-concrete beams it was found that cracks were likely to form when shearing stresses were considerably lower than those which it seemed necessary to use in the design of concrete ships; yet it was not known whether these cracks were such as would permit leakage of water through them or not. Tests were made in which hollow beams were loaded in such a way as to cause diagonal tension cracks in the side walls at the same time that the beam was filled with water, which was maintained under pressure varying in head from 15 to 30 feet. These tests indicated that the smallest crack which could be detected, say, 0.001 inch or less in width, would permit the passage of enough water to cause a moist surface on the outside around the crack. As the crack width increased the leakage increased rapidly, provided that time was not given for the closing up of cracks by the deposit of sediment of any kind. When the crack was 0.01 inch wide water spurted clear of the outer surface of the beam. When the beam was allowed to stand overnight with the pressure head and the load maintained the leakage was decreased markedly. This was probably due to the deposit of a substance which helped to fill up the cracks. Further indication of this was shown by the appearance of efflorescence on the surface of the beam in the neighborhood of the cracks. If the cracks had been very small at the time of their formation and had developed very slowly, it is possible that the silting would have kept up with the opening of the cracks and that leakage would not have occurred. Apparently this is what has happened with some of the concrete ships and barges which are afloat. An inspection made on a concrete ship which had been in the water about a year showed the presence of cracks which were large enough to cause leakage under the conditions to which these test beams were subjected. However there was no leakage, although the cracks were below the water line, and apparently there had been none. There was efflorescence apparent at cracks on the inside of the hull, indicating that the process of silting had been taking place.

Sheer and Compression in Reinforced-Concrete Beams.—These tests were begun as a part of the study of reinforced concrete in adapting it to use for the construction of concrete ships. One of the first serious difficulties in the designing of concrete ships was that of getting sufficient strength to prevent cracks forming diagonally in the vertical sides of a ship of practicable weight. Using the methods ordinarily employed in reinforced-concrete design, a shell thickness of at least 15 inches would have been required instead of the 4 inches used in the 3,500-ton cargo ship. Tests of large reinforced-concrete beams were started to make certain that no mistake was being made in using a 4-inch shell. These first tests were made on (*a*) beams 4 feet 4 inches deep and 18 feet 6 inches long; (*b*) one beam 10 feet deep and 22 feet long; and (*c*) specimen ship frames of full-sized scross section and 20-foot span. The frames were cut off at a point corresponding to the point of inflection, or 4 feet 6 inches above the top of the keel. The tests were made in the 10,000,000-pound testing machine at the Pittsburgh laboratory of the Bureau of Standards.

For the beams the load was applied at the center of the span upon the upper flange. The beams were supported at each end on a steel-plate girder. The beam, 10 feet deep, was first loaded 40 times with 640,000 pounds, which was four times as much as the maximum which the standards of the joint committee on concrete and reinforced concrete would have allowed as its working load. The widest crack at the first application of this load was 0.013 inch, and with 40 repetitions of the load, there was no appreciable increase in the widths of the cracks. The beam was then inverted and load was applied in the opposite direction, causing failure at 1,363,000 pounds, or nine times as much as the joint committee standards for reinforced-concrete design would have allowed as a working load.

The ship frames were tested by applying first only a vertical load and adding later a horizontal load at the sides corresponding to the horizontal water pressure on the sides of the ship. It was found that the strength here was about eight times as great as the joint committee recommendations allowed for the working load, also that the shear due to the horizontal forces reduced the stresses set up by the shear due to the vertical forces; in other words, that the horizontal water pressure would reduce the stresses caused by the vertical shearing forces on the frame.

These tests made it possible to design with confidence for shear in reinforced-concrete ships, using working stresses much higher than those which are recognized by the final report of the joint committee. In effect, the joint committee report limits the amount of web reinforcement to about three-fourths of 1 per cent, while these tests show that for deep beams a much larger amount of reinforcement would be effective. Apparently the main reason for the higher shearing strengths found in these tests is the larger percentage of web reinforcement which may be used effectively in deep beams where the web bars have much better chance for anchorage than in shallow beams.

After these preliminary tests were completed a more nearly exhaustive investigation was initiated at Lehigh University, Bethlehem, Pa., for the Concrete Ship Section of the Emergency Fleet Corporation.

In the economical use of building materials the importance of using higher shearing stresses in reinforced-concrete beams has been recognized by many. The results of the tests made for the Concrete Ship Section were so significant in this direction that the Bureau of Standards continued the investigation after the program of tests as related to concrete ships was completed. In all 172 beams have been tested, and the results have been quite fully worked up, giving data for a technologic paper which should be of much importance to the reinforced-concrete industry.

The conclusion from these tests is that not only working stresses in shear may properly be increased, but that they may be increased to such an extent that other features of the design become the controlling features. In order to make use of the high shearing stresses permitted, compressive stresses would be increased beyond all present reasonable values. This led to the making of tests to determine if an increase in compressive stresses was permissible. These tests were only four in number and not sufficient to afford a basis for a general conclusion, but, so far as they go, they indicate that higher working stresses in compression than are now generally recognized could be used with safety. It is important that further tests of this kind be made.

Reinforcement for Concrete Slabs.—There has been much uncertainty as to the relative economies of reinforcing slabs with (*a*) bars in the direction of the span, (*b*) bars making some angle with the span, and (*c*) expanded metal. Twenty-six slabs 4 inches thick were tested, in each of which one of the three methods of reinforcing described above was used. The results as they stand indicate that the largest amount of steel is required in the case in which the bars are placed diagonally with the span, and that as regards quantity of steel required there is a slight advantage for expanded metal over the use of bars in the direction of the span. However, certain conditions of the tests make it important that more tests be made before this question is considered to be settled.

Length of Lap Required for Reinforcing Bars.—Tests were made to determine how great a length of lap is necessary for cases in which the reinforcing bars used are shorter than the span and are spliced by lapping them in the center of the span. Four beams were made in this series, and the indication from the test results is that for this size of bar (one-half inch round) a lap of about 50 diameters is required. The concrete used in these beams had a strength of about 5,000 pounds per square inch, and it is to be expected that with a leaner concrete a larger lap would be necessary. Some information from tests in which expanded-metal reinforcement was lapped in the same way is available. As to quantity of steel required for the lap, this indicates a slight advantage in favor of expanded metal.

Value of Brackets and Haunches in Flanges.—For purposes of architectural effect, or for increasing the strength, connections between columns and beams are frequently provided with brackets. This development sometimes takes the form of an arch construction. However, in the design little attempt is usually made to determine how much strength is added by the presence of the haunch, and usually advantage is taken of only a portion of the value of the haunch or bracket. In the design of reinforced-concrete ships the strength value of such brackets is of much importance. To obtain information on this subject, a series of tests was made, including as test specimens eight reinforced-concrete frames having a span of 14 feet, a height of 7 feet, and brackets ranging from no bracket to one so large as to give the appearance of an arch. These tests indicated that the brackets had much more value in strengthening the frames than that for which allowance is usually made in the design. The results are of much importance, since the weight of the frames in a concrete ship can be reduced materially by taking full account of the strength added by the brackets in the frames. If the results are adapted to general design in reinforced concrete, they will have an important bearing on the reinforced-concrete industries where such structures are involved.

Shrinkage of Concrete in Setting as Related to Concrete-Ship Construction.—It is recognized that shrinkage of concrete occurs during setting. In many constructions this is manifested through cracks which appear in the concrete surface, but the laws which govern this shrinkage have not been very thoroughly determined. This subject becomes important in connection with the concrete ship, since, as pointed out in a previous paragraph, the smallest cracks will permit a slight leakage unless silting prevents it. In one of the barges constructed by the Emergency Fleet Corporation for the In-

142289—19——14

land Waterways Commission a series of careful measurements was made in the effort to determine why more frequent and larger cracks occurred in this barge than occurred in the others. While the effort was not entirely successful, the measurements did show that there was an elongation and shortening of the barge which corresponded closely to even the slightest rise and fall of temperature. With any rise in temperature the cracks began to close, while with a decrease in temperature the cracks opened. The largest crack present was less than 0.01 inch, and although the barge was not loaded the results of examinations of concrete ships which have been in service indicate that a deposit of silt or efflorescence will prevent leakage through cracks of this size.

Reinforced-Concrete Freight Car.—During the year a gondola freight car with superstructure of reinforced concrete was designed and built by J. B. Strauss, consulting engineer, Chicago. During the construction of this car a representative of the Bureau of Standards advised with Mr. Strauss and made an inspection of it after its completion and inauguration into service. After the car had been in service about three months, during a part of which time it was used for hauling coal, an inspection of it was made at Washington by representatives of the Bureau. This indicated that although there was some abrasion of projecting parts, this car had stood up fairly well under service conditions.

Reinforced-Concrete Flat-Slab Design.—Several urgent applications for investigational work on the reinforced-concrete flat slab have been made by those commercially interested. With two exceptions it has not been possible to make these investigations on account of the interference with war work. Plans have been projected by which a long series of tests of slabs conforming to various designs would be carried out. An expression of the willingness of certain interested concerns to cooperate in this work has been secured, but at the present time funds are lacking with which to meet the part which it seems proper that the Bureau of Standards should assume. One of the investigations now under way would have afforded a good starting point for this investigation, but the lack of funds to carry out the work together with the importance of starting the present investigation at once rendered this impracticable.

The controversy over the proper moment coefficients for flat slabs is acute throughout the country, and a thorough investigation of their merits should be made. The expense is too great for any one commercial concern to undertake it alone, and the competition between proprietary interests has been so great as to prevent cooperation among them to accomplish this purpose. The recent expiration of the basic patents on the flat slab will tend to remove this restraint, and it seems feasible to obtain cooperation of those commercially interested in this problem to the end of making a thorough investigation.

Miscellaneous Concrete Investigations and Tests.

Light-weight aggregates.—The investigation of light-weight aggregates for concrete ships begun during the past year was continued. Twelve burnt-clay aggregates were tested, these tests aiding in the selection of a light-weight aggregate by the Emergency Fleet Corporation for use in concrete ships. The aggregate produced commercially was a light-weight burnt clay made by "puffing" or "bloating" a clay or shale in a stationary brick kiln or a rotary cement kiln.

The Bureau tests of the best varieties of this aggregate showed that it would give a satisfactory strength (from 4,700 to 5,700 pounds per square inch at 28 days) when used in a $1:\frac{2}{3}:1\frac{1}{3}$ mix and would give a concrete weighing from 110 to 115 pounds per cubic foot (about three-fourths as much as ordinary concrete). Tests were also made using these light-weight aggregates in 1:1:1 and 1:1:2 mixes. During the investigation several varieties of slag were tested and generally gave satisfactory strength results, but did not produce so light a concrete. Coke as an aggregate gave light concrete, but was slightly inferior in strength. Seven varieties of vesicular, basaltic, or volcanic rocks were tested for this purpose. In general, these give satisfactory strength, but produced slightly heavier concrete than the clay aggregates. Several other rock aggregates were tested.

Permeability tests were made comparing several of the clay aggregate concretes, with sand-gravel concrete of the same mix, and, although the tests were limited and not conclusive, they indicate that the concrete made of clay aggregates is at least as impermeable to water as that made with sand and gravel. Absorption tests show that clay-aggregate concrete is more absorptive than sand-gravel concrete. For a 1:1:2 mix, sand-gravel concrete showed 8 to 10 per cent absorption in terms of dry weight, while clay-aggregate concrete gave 12 to 18 per cent. Tests showed that the modulus of elasticity of clay-aggregate concrete is slightly slower, but nearly the same as that of concrete made of sand and gravel.

Cement Gun.—An extensive series of tests was made on gunite in cooperation with the United States Shipping Board to determine the suitability of this material for use in concrete ships. The different phases of the question investigated were as follows: The effect of shooting the material in a number of layers at different intervals, the effect of shooting the specimens in vertical and horizontal positions, the strength of different gradations of the aggregate and different proportions of cement to aggregate, the effect of different pressures for shooting the material, the effect of shooting the material through screens composed of various sizes and spacings of reinforcing rods, and the comparison of the concrete made with the cement gun and the same made by the usual process. Strength tests were made both perpendicular and parallel to the direction of shooting. The series consisted of 175 slabs of the material which were sawed into test specimens on the machines in the laboratories of the Bureau.

The report on this investigation is being prepared by the Concrete Ship Section of the United States Shipping Board, and no analysis of the results has been attempted by this Bureau. However, an interesting feature of the tests which stands out quite clearly may be mentioned, viz., that the gunite specimens showed a marked increase in compressive strength over concrete slabs fabricated in the usual manner. This increase for the different proportions and gradations ranged from 23 to 70 per cent. One explanation of this probably lies in the fact that the gunite can be placed in a drier consistency than that required for pouring.

Concrete Atomizer.—A series of tests was made on concrete fabricated with the Brown atomizer. This investigation was also made in cooperation with the United States Shipping Board to determine the suitability of the material for use in concrete ships. The phases of this question investigated were as follows: Effect of various proportions of cement to aggregate, effect of different consistencies, the effect of different pressures of shooting, effect of blowing the specimens with cold air (i. e., at outdoor temperatures), hot air, steam, and a mixture of steam and hot air. The specimens were made by shooting the concrete in forms which were divided into compartments by horizontal and vertical rods. After the concrete had hardened sufficiently the rods were drawn, which permitted the specimens to be easily broken out from the slab. Satisfactory results were obtained by blowing specimens with both cold air and hot air, but the ones blown with steam were not satisfactory on account of too much water of condensation entering the concrete. This was thought to be due to the fact that a long steam pipe was used without insulation. The report of this investigation will be published by the United States Shipping Board.

Field Control of Concrete Used in Concrete Barges.—A representative of the Bureau aided in the control of the concrete that was used in the initial pourings of the New York State Canal concrete barges that were being constructed for the Railroad Administration supervised by the Emergency Fleet Corporation. This consisted of laboratory tests of the aggregates to be used, the regulation of the mixture and consistency on the job, and the taking of test cylinders of the concrete actually placed.

Corrosion of Reinforcement Due to Use of Calcium Chloride in Gauging Water.—Plain and galvanized wire mesh embedded in slabs of 1:2 and 1:3 river-sand mortar gauged with plain water and with a 4 per cent solution of calcium chloride showed that at the end of two years the corrosive effect of the salt introduced into the mortar was very marked. Plain wire mesh embedded in 1:3 mortar was attacked the most, being completely eaten through in places. The galvanized metal was attacked seriously, although not as badly as the plain mesh. The metal embedded in 1:2 mortar was not so badly attacked as that embedded in 1:3 mortar. In all cases of the metal, both plain and galvanized, embedded in mortar gauged with plain water, the reinforcement was in excellent condition and was not rusted and demonstrated the protection afforded by Portland cement. A comparison of the condition of the reinforcement embedded for two years and that embedded for one year showed that the rusting due to calcium chloride was progressive and becomes worse with age. Reinforcing rods embedded in 1:2:4 and 1:1½:3 concrete made with and without calcium chloride also showed a corrosion due to the calcium chloride, but to a somewhat lesser extent.

Paper Molds.—A paper mold for use as the form in which to cast 6 by 12 inch concrete test cylinders was developed for use in molding samples of field concrete. The distinctive improvement in the mold is that it is slit lengthwise in order to allow nesting during shipment and that it can be assembled at the job by lacing up with a stapling machine. Each paper mold weighs only 7 ounces (one-fiftieth as much as a steel mold of the same size), and 25 of them nested for shipment occupy only about as much space as a steel mold and weigh half as much. A two-ply cardboard cylinder, such as is usually manufactured, slit lengthwise, and then dipped in paraffin, to make it waterproof, is used. This type of paper mold has been used by the Concrete Ship Section of the Emergency Fleet Corporation to obtain samples of concrete used in the concrete ships and barges built by it.

Method of Mixing Concrete.—To determine the benefit to strength due to mixing of cement and water for a long period (15 to 30 minutes), and then adding aggregate to produce a concrete instead of the ordinary method of mixing cement, aggregate, and water together for one to two minutes, comparative tests of concrete by the two methods were made, using exactly the same materials and amount of water. The compressive strengths obtained were about the same, indicating that there is no advantage in long premixing of cement and water from the standpoint of strength.

Tests of Diatomaceous Earth as a Blend and Admixture in Portland Cement.—Tests made using diatomaceous earth or kieselguhr as a blending material or an admixture to Portland cement show that in general the strength of concrete and mortar made with the blended cement is weaker than that made of pure Portland cement. Absorption of concrete and mortar made with blended cement has been found to be greater.

Tests of Old Storage Cement.—During the progress of the war large stocks of cement were often shipped to various jobs at the beginning of the work and stored until needed. In some cases this storage period amounted to more than a year, and several such samples were submitted for test. The results of tests indicated reduction in strength for the storage cement, but this change was not marked for material which had been stored on the job for less than one year. One lot which had been in storage over two years gave the same strength in compression for 1:1½:3 concrete as was obtained for a 1:2:4 concrete made with the same brand of new cement. The old cement when gauged with a 5 per cent calcium-chloride solution showed an increase of about 30 per cent at seven days over the same cement gauged with ordinary mixing water.

Inspection of Buildings and Other Structures.—Assistance has been given two Government departments during the past year in connection with concrete structures under construction in cold weather. In one case, after partially stripping the forms from the A frame of a concrete dam, the concrete appeared only partially set and the quality of both cement and aggregates was questioned. Inspection showed the concrete not to have been frozen, but the hardening to have been retarded by low temperatures, and it was recommended that the mass be protected from possibility of freezing and allowed to stand. Tests showed the cement and aggregates to be of good quality and that with the usual cold-weather precautions good quality concrete would result. In the second case a concrete roof was poured just previous to a drop in temperature, with the result that the upper surface for a depth of one-half to 1 inch was frozen. Rather than tear out the injured section of roof it was recommended that a load test be applied after the usual period of curing. The results of this test proved that the frozen slab had the necessary structural strength, and removal was not necessary.

The marble floor of the Arlington Memorial Amphitheater has been developing rather extensive cracks, these being noticed before the completion of the floor in the spring of 1918. Several inspections were made and laboratory tests were made on the floor materials. The very rigid construction of the floor and the wide range of temperature to which it is subjected appear to be the chief causes of the cracking. A report embodying the results of the studies was submitted to the Arlington Memorial Amphitheater Commission.

Inspections have also been made of the ornamental concrete and stuccowork at Meridian Hill Park and East Potomac Park at the request of the Committee on Public Buildings and Grounds. These structures show only minor defects resulting from slight faults in design and are excellent examples of the architectural possibilities in surface-treated concrete.

Miscellaneous Tests.—Aside from the tests reported in the preceding paragraphs, numerous tests of a miscellaneous nature have been performed for the Government departments, as follows: Tests of sands, sea shells, gravels, and stones to determine their suitability for use as concrete aggregates; sieve analyses of sands, silica grits, silica washes, and granulated cork; transverse strength and absorption tests of brick; compressive strength of concrete cubes and cylinders; permeability tests of concrete and bituminous waterproofing felts.

Tests of Cement for Governmental Purposes.

During the first part of the past year the testing of Portland cement for the different branches of the Government far exceeded the amounts ever tested during a similar period. As a result, the total amount sampled, tested, and shipped for the entire year largely exceeded that of any previous year. There were sampled 426,878 barrels. Of this amount 296,705 barrels were shipped, 35,000 barrels were withdrawn by the manufactures on account of unsatisfactory tests as determined by them before the Bureau made its tests, and 75,000 barrels were rejected by the Bureau on account of failure to meet the requirements of the specifications. The withdrawals and rejections also far exceeded those of previous years, but it was due entirely to unsatisfactory labor conditions at the plants.. The manufacturers were constantly forced to replace skilled labor with new, which always tends to interfere with proper production.

Soundness of Portland Cement.

In the course of the investigation of Portland cement which the Bureau has been conducting for years it has produced in its experimental plant a number of cements which were unsound according to the "boiling test." Neat, mortar, and concrete specimens were made of these cements, and they have been under observation for approximately five years. Depending upon whether the disintegration in the "boiling test" was very slight or very marked, the neat and mortar specimens showed expansion and cracking in from three months to one year. However, this expansion was not uniform throughout the specimen, but was always decidedly less on that surface exposed to the air during the first 24 hours' storage in the damp closet, the surface frequently not cracking at all, while the opposite side would show large cracks. This caused a bending of the specimen. The strength of the small specimens was usually very high at the early periods of testing.

The differences in the concrete specimens were very noticeable. These specimens, made for the determination of compressive strength and stored in the damp closet, do not show any cracking or marked loss of strength. The concrete specimens made for the determination of the coefficient of expansion show excessive expansion and disintegration when stored in the air of the laboratory. The latter is not manifested by cracking, but by crumbling under slight abrasion. Specimens made at the same time, but stored in water, are apparently sound, being free of cracks and very hard, but show very marked expansion, amounting to one-tenth of 1 per cent or more. Notwithstanding the apparent soundness of the concrete, when stored in the damp closet or in water the expansion, as shown only by actual measurement, shows this cement to be of questionable value, and in a manner justifies the use of the present "boiling test."

Magnesia Content of Portland Cement.

Notwithstanding the fact that all the specifications for Portland cement in this country within the past few years have raised the allowable magnesia content of Portland cement to 5 per cent, there seems to be a desire to raise this amount still further. This matter is covered in Technologic Paper No. 102 of the Bureau, wherein the change in constitution and properties of Portland cement with a change in magnesia content of from 2 to 25 per cent was studied. Briefly, the conclusions were that there was no marked change until the amount exceeded approximately 7 per cent.

At the time the above-mentioned paper was issued, the concrete made from the cements in question had been under observation for about two and a half years. The majority of the specimens are now five years old. It is not the intention to break these and secure quantitative data before there are evidences of disintegration shown by the very high magnesia cement concrete. At the end of five years, however, all are apparently in excellent condition, without any signs of disintegration. Furthermore, it should be borne in mind that the chief fault of the high magnesia cements (MgO exceeding 7 per cent) was largely that of very low strength at early periods. Disintegration was not a noticeable feature of the concretes at any period, though mortar-and-neat test pieces made from cements containing magnesia in excess of 10 per cent disintegrated in from one to three years.

Magnesium Oxychloride (Sorel) Cements.

The development of tests for use in specifications covering the purchase of magnesia for use in magnesium-oxychloride cements has not progressed very satisfactorily. The principal difficulty is the different action of the cement in mixtures used in flooring or stucco from that when used with a standard reproducible aggregate or standard Ottawa sand. In practice one of the aggregates is a fibrous material, as asbestos or sawdust. On account of the manner in which these latter occur, it is practically impossible to secure similar materials (as to fineness, length of fiber, thickness of fiber, etc.) at different times. Therefore, it would seem to be very unsatisfactory to use these in a standard test. These cements, however, do require a fibrous aggregate to reduce the marked volume changes which occur in their setting and hardening. Consequently, standard sand does not seem to furnish an aggregate which gives results that can be correlated with those obtained from a fibrous aggregate or in general practice. Further work is being carried on along this line, however.

At the present time the Bureau is receiving samples from shipments received by a number of composition-flooring manufacturers. Test pieces are being made with these of both a flooring and standard sand mix to determine both the tensile and compressive strengths at different periods and the coefficient of expansion. At the same time the manufacturer is making particular note of the results he obtains in practice with these same shipments.

Concrete Columns with Cast-Iron Cores.

The results of the investigation of the strengths of these columns are incorporated in Technologic Paper No. 122, now in press. Eighteen columns for tests were fabricated by L. J. Mensch, consulting engineer, under the Emperger system of reinforcing, in which cast-iron cores are used as the reinforcing material. The columns ranged in length from 6 to 14 feet and were 13 inches in diameter. The cast-iron cores were 6-inch hollow cylinders, three-fourths of an inch thick, and were placed concentric with the axes of columns. The total loads borne by these columns varied from a minimum of 858,000 pounds to a maximum of 1,041,000 pounds, or 6,700 and 8,160 pounds per square inch, respectively, on the basis of equivalent columns of solid concrete; that is, were about twice the usual strengths for such columns as ordinarily reinforced.

The cost of fabrication of this class of columns is considerably less than ordinary concrete construction to carry the same loads and approximately half that of a steel column of the same strength. The rather remarkable showing as regards strength and ease of fabrication suggests that this type of construction be studied by practical structural engineers with a view to a possible wider introduction in building practice.

LIME, GYPSUM, ETC.

(The work of the section was somewhat interrupted by moving the laboratory from Pittsburgh to Washington. The delay incurred was magnified because it was accompanied by an almost complete change of personnel. The section is now established in its new quarters in Washington and is better equipped than it has ever been.)

Cooperation with Lime Manufacturers.

All of the manufacturing interests with which this section deals have accorded official recognition of the work. The Lime Association, the Gypsum Industries Association, and the Sand-Lime Brick Association have all appointed, within the past year, special committees on cooperation with the Bureau of Standards.

At its last annual meeting the Sand-Lime Brick Association passed a commendatory resolution, which has been engrossed and presented to the Bureau.

The section has continued its active cooperation with the American Society for Testing Materials, and during the past year its members have accepted the chairmanships of the subcommittees on specifications for structural lime, on methods for measuring plasticity, and on methods of test for gypsum products.

On January 6, 1919, at the instigation of this section, there was formed an interdepartmental conference on chemical lime. This conference is composed of 15 members, 4 of whom represent the Bureau of Standards.

Compressive Strength of Cement-Lime Mortars.

The extended use of mixtures of lime and cement as mortar for laying brick has brought about a demand for information as to the way in which the properties of such mortars vary with their composition. It was found that the strength of such mortars is proportional to the quantity of cement contained in them and to the density of the mortar. This latter factor is affected by the quantity of lime added. The detailed results were published in the Journal of the American Ceramic Society for January, 1919.

Effect of Addition of Hydrated Lime Upon Properties of Concrete.

This work, which was started in 1915, was continued during the past year by conducting experiments under field conditions at Cedar Hollow, Pa. Concrete with and without lime was mixed in the ordinary type of concrete mixer and allowed to flow down a chute 100 feet long. The effect of the lime upon the time required to flow down the chute and upon the other properties of the concrete was determined. This work is conducted under the guidance of a special advisory committee appointed by the Bureau for the purpose. The results of the Cedar Hollow experiments were presented to this committee on June 24, 1919. The committee decided that the information at hand is not sufficiently complete to warrant the publishing of anything at present. A program for the present year's work was mapped out at that meeting.

Carson Plumb Bob Test.

A method of test, wherein a plumb bob was used to determine the properties of lime plaster, was devised by William E. Carson. At the request of the subcommittee on structural lime of the American Society for Testing Materials, the Bureau conducted an investigation to determine the practicability of this test. A favorable report was presented to the committee, but no action has as yet been taken in the matter.

Possible Causes of Unsoundness of Lime Plasters.

The "popping" of lime plaster is very unusual, but when it does occur, it is sufficiently serious to warrant an investigation as to its cause. Apparently little particles of the plaster expand enough to push themselves clear out of the wall, leaving "pin holes" in the plaster. This occurs from six months to two years after the wall has been plastered. Our investigation includes making specimens of plaster to which has been added known quantities of suspected ingredients, storing them in the air, and watching them for signs of popping. While some of the samples have failed already, the specimens are not yet old enough to be sure that those which are now sound will remain so.

Measurement of Plasticity.

Plasticity—ease of spreading—is the property which virtually controls the selling price of hydrated lime; yet there is no generally accepted method for measuring this property. For many years the Bureau has been designing instruments to measure plasticity, experimenting with them, noting their defects, and redesigning them. This year one instrument was designed in February and put into operation in May. To date, it has not given entire satisfaction. Another instrument, of much more elaborate and complicated type, which was designed in 1917, has just been completed. The principle upon which these instruments operate has gradually been evolved until reasonable assurance is felt that it is correct. The changes made are rather in details of design and operation.

The method of measuring plasticity developed for lime should be equally applicable to gypsum and all wall plasters.

Standard Sand.

For almost every purpose lime is mixed with sand before it is used. Obviously laboratory tests should, therefore, be made not on the lime itself, but on sanded mortars made from the lime. For this purpose, it is necessary to establish arbitrarily a standard sand in order that every laboratory in the country using the same sand may obtain comparable results. In cooperation with the American Society for Testing Materials, the Bureau has undertaken to write the specifications for this sand. The task is to find a sand which is satisfactory for the purpose and which can be obtained uniform in quality. The work has not yet been completed.

For the reasons given above a standard sand is also essential for tests of gypsum. Probably the same sand can be used with both materials.

Reinforced Gypsum.

Shortly before the entrance of the United States into the war the application of reinforced gypsum to roof construction was developed by one of the largest manufacturers of gypsum in the United States. A considerable amount of scientific work was done which afforded a sound basis for the design. With these data as a basis, a member of the Bureau of Standards' staff has participated actively in the formulation of standards for design of reinforced gypsum. These standards have been accepted as a tentative report to the American Society for Testing Materials and are being printed in the proceedings for 1919. During the war many thousand square feet of reinforced gypsum roof designed by these standards were used in Government buildings.

Factors Influencing Time of Set of Gypsum.

The standard method for measuring the time of set of calcined gypsum has not yet come into general use; it is still subject to modifications. This study was undertaken to determine the effect of certain changes in the method of manipulation. It was found that the addition of excess water to the gypsum makes it set more slowly; that if the gypsum and water are mixed vigorously the set will be hastened; that the temperature of the water has nothing to do with the time of set. The detailed results of this work were published in the Journal of the American Ceramic Society for August, 1918.

Increasing the Strength of Gypsum and Making it Waterproof.

Gypsum is now used for the manufacture of hollow tile and of reinforced roofs. Its inability to withstand the action of the weather limits its field of application. After a number of experiments a method of manufacture was evolved whereby gypsum tile may be produced having, when compared with ordinary tile, three times the strength and three times the ability to resist erosion by water. These results, but no details of the method, have been presented to the Gypsum Industries Association with the hope that they will take sufficient interest in the subject to put it into use.

Measurement of Properties of Commercial Gypsums.

The tentative standard methods of test for calcined gypsum as adopted by the American Society for Testing Materials in 1919 have not been used sufficiently to determine the numerical results which they will give. For example, it is not known what the tensile strength of a good gypsum should be, because so few samples have ever been tested by the standard method. For this reason the Bureau has undertaken to test about 100 samples of commercial products and to compile the results in such a way that the proper numerical values can be inserted in the specifications for these products. The tests include chemical analysis, water-carrying capacity, time of set, fineness, tensile strength, compressive strength, and yield. This work is about 20 per cent completed.

Effect of Gradation of Sand on Properties of Sand-Lime Brick.

The properties of a sand-lime brick depend very largely upon the quality of the sand of which it is made. Whether this sand is fine, course, or graded is very important. The sand used in these experiments was sifted into three sizes—fine, coarse, and medium. These were then mixed in predetermined proportions, and bricks were made of them. It was found that a mixture of 40 per cent fine sand and with 60 per cent coarse and no medium gave the strongest bricks. The detailed results were published in the proceedings of the Sand-Lime Brick Association for 1919.

Factors Influencing the Bond Between Mortar and Sand-Lime Brick.

If a chain is no stronger than its weakest link, then a pier built of good bricks and good mortar may not give satisfaction because of poor bond between the mortar and the brick. Tests of brick piers published in Bureau of Standards Technologic Paper No. 111 show that the strength of the pier will seldom exceed 30 per cent of the strength of the brick, even when the best mortar is used. Our experiments have shown that the bond between mortar and sand-lime brick is affected by two factors. One of these is the laitance. When the green brick is formed in the press, the water in the raw mix comes to the surface, carrying with it soluble salts, which are deposited as a scum. This scum, or laitance, gets between the mortar and the brick, and interferes with the adhesion. The other factor is the size, number, and shape of the pores on the surface of the brick. Sometimes the sides of these pores are bent over to form a key to which the mortar adheres strongly. Both of these factors are subject to control by varying the consistency of the raw mix and the molding pressure. An article on this subject is now in course of preparation

Effect of Duration of Hardening on Properties of Sand-Lime Brick.

The laboratory experiments on this subject, the results of which were published in the Proceedings of the Sand-Lime Brick Association for 1918, showed that nothing is to be gained by curing the brick for more than four hours. This curing is done by exposing the brick to high-pressure steam for from 7 to 12 hours. Such a marked reduction in the time would, therefore, result in an enormous saving of fuel, to say nothing of the additional output possible with the same equipment and overhead. The manufacturers took up the idea with avidity and volunteered to cure brick for different periods of time and send them to the Bureau to be tested. This was to make sure that the results obtained in the laboratory could be duplicated on a large scale. Owing to the unusual business conditions some of the manufacturers have not yet been able to make the samples for the Bureau. The work is at present about 40 per cent completed.

Routine and Miscellaneous Work.

A lime manufacturer was receiving complaints that his hydrate was not plastic. A week spent at his plant studying the conditions showed that the trouble was due to overburning the lime; and recommendations were made accordingly. Samples of this hydrate received at frequent intervals since then indicate that the trouble has been overcome.

At the request of the Industrial Cooperation Service, the manufacture of sorel cement was investigated. This cement was being used for drain boards, table tops, etc., and the sawdust added to it as a filler was proving objectionable because of discoloration. After numerous tests the Bureau learned how to make these articles, using sand instead of sawdust, without impairing the peculiar characteristics of the sorel-cement surface.

An investigation of the waste shells from the pearl-button industry indicated that, while they could be calcined to produce a good quality of lime, it would probably be better economy to market them as ground limestone.

The routine testing for Government purchase has been negligible, consisting of one sample of hydrated lime for the Supervising Architect and five samples of quicklime for the Panama Canal.

Before the armistice a great deal of time was spent in active cooperation with the Quartermaster's Department, the gas-warfare service, the forest products laboratories, and other Government agencies in enabling them to obtain the quality of lime best suited to their needs. Meetings of the War Industries Board were attended, wherein were discussed proposed specifications for magnesite stucco and for gypsum plaster board.

RUBBER.

(Investigation and testing of rubber and rubber goods to determine the physical and chemical properties and the development of specifications.)

Rubber Analysis.

On account of certain routine work on the analysis of rubber goods it became necessary to find methods for the determination of constituents not before considered. Glue is one of these constituents. Its amount can be ascertained with sufficient accuracy by determining nitrogen by the Kjeldahl method. A reliable qualitative test for glue was also devised.

Rubber soles for shoes contain cotton and other organic fillers. It is hoped that a new method for the determination of the amounts of these constituents, which is still under investigation, will soon be perfected.

Considerable time has been spent during the last six months on a new method for the determination of mineral fillers in rubber goods. Even in its present incomplete state the method gives more accurate results than can be obtained by the usual combustion method, because most of the fillers used are unchanged as the rubber goes into solution.

Very interesting results were obtained by the use of mixed solvents in extracting rubber. A paper on the subject was prepared for publication.

It is gratifying that the Bureau's methods of analyzing and testing rubber goods are generally recognized as accurate and reliable. As an illustration of this, the specifications for solid and pneumatic tires issued by the Motor Transport Corps require that these methods be employed.

Balloon Fabrics.

Many samples of balloon fabrics received for permeability and aging test were analyzed.

Rubber Tires.

In the year beginning March, 1918, over 500 samples of solid truck tires, representing about 250,000 tires, valued at about $20,000,000, were analyzed for the War Department. Army inspectors at the various plants performed most of the routine physical tests, but samples were sent regularly to the Bureau as a means of checking their results. A large part of this work was done during the period covered by this report.

The preparation of specifications for pneumatic tires and inner tubes was, for several reasons, a very difficult task, in which this Bureau cooperated. The specifications, which were issued in October, 1918, were based on an elaborate series of physical tests and chemical analyses made at the Bureau. A large number of tires and tubes, representing the products of numerous manufacturers, were used for this work. The number of samples it was proposed to send for analysis was so great that immediate arrangements had to be made for a larger force of chemists and more commodious quarters. The Bureau must thank the Municipal University of Akron, Ohio, for the use of the space and facilities necessary. This was particularly fortunate, because Akron is the greatest center for the manufacture of tires.

Approval of tires and inner tubes for purchase by the Motor Transport Corps was based on the results of tests and analyses made by the Bureau of Standards in accordance with their specifications.

Owing to the armistice, the branch laboratory in Akron was never utilized to its full capacity, and it was abandoned in June, 1919.

Assistance Rendered Manufacturer of Solid Rubber Tires.

Assistance was rendered a manufacturer of solid-rubber tires in improving the quality of the compounds used, and in improving the bond or adhesion between the tread stock and the hard-rubber base. Various formulas, based on a three-hour cure, were suggested by the chemical division and made up, cured, and tested in the physical laboratory. A solid tire which met all the requirements was developed. This involved a physical and chemical study of the nature of the bond between hard and soft rubber. Some interesting data on this subject were obtained.

Power Loss in Automobile Tires.

An investigation will be undertaken to determine the power loss or energy absorbed by different types of automobile tires, and to study the effect of "tire fillers" on the life of pneumatic tires and the power absorbed as compared with the power absorbed when inflated with air. Special equipment in the way of electrical absorption dynamometers is being installed for this work.

Rubber Packings.

These are needed in the recoil cylinders of field guns. Work was started over a year ago, since which time samples submitted by manufacturers have been tested. A recent undertaking was the development of an oilproof packing in cooperation with a concern manufacturing air brakes. The Bureau's rubber plant is being used in connection with the compounding and vulcanization of experimental mixtures for trial packings.

Hospital Supplies.

Many samples of rubber sheeting, tubing, hot-water bottles, air cushions, surgeons' gloves, etc., were tested and analyzed for the Field Medical Supply Depot. The Bureau has been requested to prepare standard specifications for the purchase of these materials.

Tests of Fire Hose for Government Departments.

During the past year the Bureau continued its cooperation with Government departments in testing fire hose. All fire hose used by the local fire department is purchased on the basis of tests conducted at the Bureau. Tests of this sort were also made for the Panama Canal and for the General Engineer Depot of the Army.

Rubber Jar Rings for Canning.

A very important item in connection with the matter of food conservation is the subject of jar rings. The Bureau was requested by the States' Relations Service of the Department of Agriculture to cooperate in the production of standard specifications for jar rings in order to establish a standard of quality for use by the public and to eliminate the many inferior brands of rings that had been the cause of extravagant waste as a result of food imperfectly preserved.

The Bureau's method of procedure was to investigate the physical and chemical properties of the various grades of jar rings on the market and to compare the results obtained with the known behavior of the rings in service. It was found that of the many different grades of commercial rings obtainable those having certain physical properties that are easily measurable may be depended upon to give satisfactory results. Specifications written by the Bureau included a series of simple tests and measurements, and the specifications are now published by the Department of Agriculture and recommended for use by the public.

Miscellaneous Rubber Goods.

Rubber hose of different kinds, such as are used for steam, water, air, etc., together with miscellaneous rubber goods, such as belting, valves, and packings, commonly classed as "mechanical rubber goods," were investigated by the Bureau at the request of the War Department. The object was to develop standard specifications for materials of this sort to be used as a basis of award in the purchase of supplies for military purposes.

The methods followed in investigating and correlating the physical and chemical properties of the various kinds of rubber goods had, for the most part, been previously developed at the Bureau in connection with similar work for other Government departments. In addition to chemical analyses to determine the percentage of rubber present and its quality physical tests were made to measure the quality and strength of fabric and the strength, stretch, and elasticity of the rubber as an indication of the correctness of vulcanization. A study and comparison was made of various articles in each of the numerous classes of materials as a means of judging the excellence of fabrication. When practicable, the materials were subjected to conditions approximating those of service, and in some cases accelerated aging tests were conducted as a means of estimating the relative life of the rubber compounds used.

As a result of the laboratory investigations referred to and numerous conferences with manufacturers and representatives of the War Department standard specifications have been adopted for practically all miscellaneous rubber goods used for military purposes.

During the past year a total of 994 miscellaneous samples were tested physically and in many cases subjected to chemical analyses. The following items are representative of the materials handled: Rubber hose (fire, water, air, air-brake, suction, steam, etc.), 98; rubber-covered wire, 110; packing (asbestos and rubber, square spiral steam, plain sheet, sheet-wire insertion, asbestos sheeting, etc.), 102; jar rings, 82; dredging sleeves, 55; asbestos gaskets, 34; automobile, motorcycle, and bicycle pneumatic tires, 128; inner tubes, 50; solid tires, 44; rubber bands, 11; gas-mask check valves and nose pads, 42.

The majority of these tests were made at the request of the Motor Transport Corps, the General Engineer Depot, the Chemical Warfare Service, the Signal Corps, Medical Supply Depot, the Panama Canal, and the General Supply Committee in connection with contracts and to secure experimental data for use in the preparation of specifications.

Future Work in Rubber.

An interesting program of investigations on problems relating to rubber was mapped out. It is hoped that satisfactory progress can be made during the next year.

The increased laboratary space provided for the experimental rubber plant in the new industrial building will make it possible to handle a greater volume of tests and to perform investigations on a larger and more comprehensive scale than in the past. In the new laboratory the vulcanizer will be equipped with automatic temperature and time controllers and recording thermometers, which will eliminate certain errors in temperature regulation due to the use of steam-pressure reducing valves.

LEATHER.

(Investigation and testing of leather and leather goods to determine the physical and chemical properties and the relative durability of different kinds of leather upon which to base standards of quality.)

After the signing of the armistice the requirements of the War Department for leather goods were greatly decreased, and hence the amount of routing testing work was considerably reduced. This fact has allowed the personnel of the leather laboratories to devote nearly their whole time to investigation and research during the greater part of the fiscal year. The results of many individual investigations have been obtained and several new problems have been started. The general plan followed has been to correlate, in so far as possible, the tensile strength, stretch, buckle strength, water absorption, and wear, with the chemical composition, of the particular leather involved. Owing to the nature of the material, the methods for the analysis of leather are almost entirely empirical. It is nearly impossible to check the accuracy of a given procedure by analyzing samples of leather prepared so as to contain a known percentage of a given constituent. For this reason the methods adopted by the American Leather Chemists' Association are followed closely by this Bureau. The work during the fiscal year may be divided into the following parts: Sole leather, harness and strap leather, upper leather, miscellaneous, development of specifications, and routine testing.

Sole Leather.

On pages 154 and 155 of the last annual report mention is made of six different problems relative to the wear of sole leather which it was proposed to investigate. Progress has been made on all of these. Preliminary results have been obtained in the investigation of the comparative wear of the belting tannage with the sole tannage, and also in the investigation to determine the effects of oils and greases on the wearing quality of sole leather, but further tests are planned before definite conclusions are drawn. Technologic Paper No. 138 contains the results of the first of a series of tests to determine the effects of glucose as well as Epsom salts on the wearing quality of sole leather. The leathers used in this test were (1) a lone-time tannage with a minimum addition of glucose and salts, (2) a leather tanned to the belting stage and then filled with the maximum amount of extract by drumming, (3) a leather tanned to the belting stage and then filled with a large amount of glucose, and (4) a leather well tanned and moderately filled with glucose and salts. All were oak-tanned leathers. All the bends were cut into soles according to a definite plan, and each individual test consisted of comparing a sole filled with glucose and salts with one with no appreciable amounts of these materials added. Both soles in any test were cut from the same relative location on the hide. Service tests were made on soldiers at Camp Meade, Md. The laboratory work consisted chiefly of abrasion tests on the laboratory wearing machine, complete chemical analyses of the new and worn soles, and water-absorption tests. The success of the work was made possible through the hearty cooperation of the War Department, the Tanners' Council, and the American Leather Research Laboratory. The second test of this series has been started, the leather used in this case being hemlock without the addition of glucose and salts, hemlock with the addition of about 10 per cent of these materials, and a long-time, oak-tanned leather. The hemlock leather was made from dry hides. The amount of water-soluble materials in the two hemlock leathers differed on an average about 11 per cent on account of the difference in glucose and salts present in each of the leathers. This fact will allow information to be obtained regarding the comparative durability of low and high water-soluble leathers. A comparison of the relative durability of oak and hemlock tannages will also be obtained from this test. A comparison of the durability of vegetable and mineral tannages will be secured from the following tests, which are in progress: (1) Oak as compared with chrome tannage from different hides, (2) oak as compared with chrome tanned from the same hide, and (3) oak as compared with alum-tanned leather from different hides. Actual service tests have also been started to determine the effect of light and heavy rolling on the durability of leather from the same hides.

Several series of tests on the wearing machine to show the relative durability of sole leather from different parts of the hide have been completed, and, together with a description of the machine and the methods of testing, will be published as a technologic paper of the Bureau.

Harness and Strap Leather.

Investigations of harness and strap leathers were started in order to learn the effects of different amounts and kinds of stuffing, and of acidity upon the strength of the leather, and upon the rate of deterioration during storage. Owing to the long life of these leathers, service tests seemed impracticable.

An attempt was made to correlate the physical properties of different harness leathers with the stuffing content of the leathers. Three distinct tests were made with three different hides. One hide was tanned as regular russet harness leather, and had one side stuffed with an average of 23 per cent grease and the other with an average of about 11 per cent. Another hide had one side given a light tannage and the other side a heavy tannage, and then both were finished as regular russet harness leather. Still another hide was tanned as regular russet harness leather, and had one side stuffed with a mixture of 50 per cent cod oil and 50 per cent tallow, and the other side stuffed with a mixture of 50 per cent mineral oil and 50 per cent tallow. These tests were conducted to show the effects of different amounts of stuffing contents, of the variation in stuffing content over the hide, of different degrees of tannage, and of animal and mineral oils on such physical properties as the tensile strength, buckle strength, and stretch. The results of these tests will be published within a short time.

Upper Leather.

Water Resistance.—Several tests were made to determine the comparative resistance to water of chrome-retanned and bark-tanned upper leather used in making Army shoes. Service tests showed that the chrome-retanned leather resisted water better than bark-tanned with the particular leathers tested. Laboratory tests showed that if properly stuffed chrome-retanned and bark-tanned upper leathers are equally resistant to water. In both cases the resistance seemed to depend entirely upon the amount of stuffing content up to the point where the pores of the leather were completely filled.

Resistance to Fermenting Animal Mixtures.—The relative resistance of chrome-tanned and bark-tanned upper leathers to fermenting mixtures of animal products was also investigated to determine the relative fitness of the two leathers for use in trench shoes. The data indicated that the chrome-retanned leather was much more resistant than the bark-tanned.

Miscellaneous.

Leather Packings.—A heat-resisting leather is needed for packing in the recoil cylinders of large guns. A number of samples furnished by the Ordnance Department and others, tanned at the Bureau, were tested by heating in mineral oil at temperatures up to 225° C. for varying lengths of time. The effects of using different stuffing mixtures were also determined.

Waterproofing Leather.—The efficiency of different experimental and commercial preparations for waterproofing leather was investigated.

Artificial Leather.—Increased use of so-called artificial leathers and the absence of satisfactory tests caused an investigation to be started and to develop standard methods of testing to determine the quality and durability of these materials.

Development of Specifications.

During the fiscal year representatives of the Bureau have assisted the War Department, Panama Canal, and the General Supply Committee in developing specifications for leather. The work consisted of acting in an advisory capacity, as well as making extensive laboratory determinations for the establishing of limits for certain constituents and physical properties of the various leathers. Much progress is expected during the coming year in developing standard specifications for leather.

Routine Testing.

As usual, a part of the time during the year was devoted to routine testing work for the various Government departments in making such tests as tensile strength, buckle strength, and chemical analyses. The materials tested included harness leather, strap leather, upper leather, sole leather, belting leather, lace leather, horsehide for baseball covers, packing leather, and waterproofing compounds.

Experimental Tannery.

Arrangements have been proposed and partially perfected for installing a small experimental tannery at the Bureau to be operated in cooperation with the Tanners' Council. Preliminary plans for a complete installation have been drawn up, and in the event of a successful termination of the plans as contemplated, the Bureau will be in a position to render valuable assistance to the leather industry in carrying out exhaustive investigations for the solution of important problems relating to the tanning and leather manufacturing industries, especially the determination of the properties upon which the quality of leather depends.

Laboratory Facilities.

The Bureau's new industrial building, which has just been completed, provides ample laboratory space for extensive research and testing in accordance with the program that has been planned, and will permit of more efficient cooperation with the various Government departments to meet their increasing demands for such work.

Additional laboratory equipment is being installed. consisting of testing machines, machines for cutting shoe soles and skiving leather, and a complete outfit for shoe-repair work.

TEXTILES.

(Investigation and testing of textiles to determine their physical and chemical properties. Development of new materials. Prepaiation of specifications.)

Although considerable work has been done for the military organizations, such as the War and Navy Departments, since the signing of the armistice, both directly and in a cooperative capacity, there has, of course, been a gradual decrease in the rendering of such services, while, on the other hand, the industries of the country have called upon the Bureau for tests, information, and cooperation even to a greater extent than in previous times.

Identification of Fibers.

The kind of service which a fabric, yarn, or material will render can always be estimated, provided an accurate knowledge of the substance is at hand. The scientific examination of such materials divides itself into three classes—physical, chemical, and microscopic—with accuracy as a chief consideration in respect to the last named. When the first two of these methods of examination do not give the results expected, the microscopic, in general, proves satisfactory.

German-Uniform Fabrics.

One of the chief uses of the microscopic method of identification was in the analysis of the fiber content of German war textiles. Airplane fabrics and uniform fabrics were examined carefully to discover substitute materials. A large shipment of uniform fabrics taken from German officers and soldiers was received from the Purchase, Storage, and Traffic Division of the War Department, to be examined carefully, tested, and studied for any useful information which might be derived thereby. From the specimens submitted it was found that the materials or fabrics used in the uniforms were much lighter in weight than those used in making woolen uniforms for American soldiers. It is thought that by a change in constructon more service could have been obtained from the German fabrics.

Ramie Felts.

Examination by the microscope and photomicrographic prints of samples of a so-called ramie felt showed that 25 per cent of the fiber content was wool taken from the back of a sheep. Further examination showed that the ramie fiber had been treated to increase its felting qualities, giving it a very fine wavy outline, and putting it in the class of fibers known as vegetable wools. Only a slight trace of cotton fiber was found.

Airplane and Balloon Fabrics.

Prints obtained from photomicrographic plates of airplane fabrics showed the penetration of dopes and pigments into the interstices of the cloth, the amount of dope and pigmented protective covering used, and the kind of bond which existed between them. The study was carried out not only on American fabrics but also on fabrics taken from wrecked or captured German airplanes.

Balloon fabrics, as well as the bonds and fastening of rubber seams of various constructions, were studied by this means with the same object as the study of airplane fabrics.

Sealskins.

In the process of determining the effect of two dyers' processes of dyeing on samples of sealskins taken from the same killing the photomicrographic examination was most helpful. Two skins, considered to be fairly representative specimens of the product of dyeing this type of fur, were submitted. At the request of the American manufacturer tests were made to compare his method of dyeing with that of a foreign dyer, the purpose being to discover the difference between the two methods. The results showed that the American method was superior. Both skins were dyed with the same dyestuff, but it was very clearly shown that, although the chemical study indicated only a wide variation in the amount of metal used as mordants, the microscopic study presented a number of distinctions which existed between the skins.

Miscellaneous Identifications.

A large number of samples of rope, twine, cord, thread, linen, flags, and other textiles were examined for the General Supply Committee.

Oakum Specifications.

The Bureau was called upon to assist in the drawing up of standard specifications for oakum for the caulking of vessels, the need for which had been greatly increased by the rapid growth of shipbuilding in this country. The War Industries Board, together with the Shipping Board, found that specifications were absolutely necessary to cover this class of material. A conference was arranged with the above-mentioned boards, together with representatives of the leading oakum manufacturers in this country.

The chief points of consideration were: (1) What constitutes a good oakum for caulking? (2) What grades of oakum should be allowed in oakum? (3) What should be the allowable per cent of tar in the product? (4) What fibers should be allowed in the different grades of oakum?

As a result of this conference, a set of specifications was produced to be used for Government purchases, and also by individual corporations. The Bureau was selected to act as referee in the event of a dispute as to the grade and percentage of ingredients of oakum, acting only in an advisory capacity.

Chemical Retting of Flax.

A great many processes were investigated as a result of the Nation-wide desire for improved methods of manufacturing. The flax industry was among the more prominent of these. It is claimed that by a chemical process the degumming and retting of flax is greatly simplified and expedited, which would result in greatly increased activity of this industry in this country. The new treatment is said to dissolve the gum from the flax straw in less than one hour, leaving fibers similar in appearance to flax obtained by processes which require the submersion of the straw in water for a period of from 15 to 25 days, or in dewy meadows for a period of time from 5 to 8 weeks, subject to atmospheric conditions. This new process is under investigation by the Bureau, but as much time is required to complete the necessary experiments a conference was arranged at this Bureau to obtain all possible information on the subject and to see what could be done to aid the situation. Representatives of Government departments interested in the subject were present and had the opportunity of witnessing a few demonstrations of the chemical process of retting. Whether these fibers differ essentially from water or dew retted fibers, and also the advantages derived from chemical retting, remains to be determined.

Cotton Goods.

The chemical work done on cotton goods intended for uniforms consisted in determining the nature of the dye and testing the fastness of the color. This was carried out in accordance with methods agreed upon by officials of the War Department interested in the subject.

Waterproofed Canvas.

Waterproofed canvas for military use must be not only thoroughly waterproof, but also resistant to mildew, free from objectionable odor or poisonous material, permanently pliable in cold weather and after prolonged exposure to sunlight. In addition to determining the nature of the waterproofing material used on many samples of tarpaulin, etc., two strenuous tests were used to imitate the effect of beating rain and of lying on wet ground. Tests were also made to learn the resistance to mildew, to cold and heat, and to sunlight.

Much of the resistance to water depends on the closeness of the weave of the cloth. When waterproofing materials were received for test they were applied to suitable canvas which showed no "pinholes" when held up against a bright light.

These waterproofing materials and commercially waterproofed tarpaulins differed widely among themselves as regards their behavior in the different tests. Analyses showed that they also differed widely in composition.

The examination of English, French, and German fabrics obtained through the War Department showed that few of them were as good as the average American canvas.

Woolen Goods.

Woolen cloth for uniforms, overcoats, shirts, and blankets was tested for fastness of color, nature of the dye, and for the amount of cotton present. A large number of felt samples were analyzed at the request of the War Department.

Commercial Dyeing Practice.

The fastness of color of cotton goods dyed in the piece depends to a considerable extent upon the skill and care of the dyer and upon the way in which the mechanical operations are performed. In cooperation with the Inspection Division, Cotton-Goods Branch, of the Quartermaster General's Office, samples from representative mills were frequently tested. This led to the recommendation of certain processes and the correction of the defects in the products of contractors who were producing faulty material.

Deficiencies in fastness of color were in many cases due to faulty mechanical processes, and not to dyes of poor quality.

American Dyes.

At the request of the Quartermaster General and the War Industries Board a collection was made of all the available colors for dyeing the olive-drab shade on cotton and wool. From these strips of cloth were dyed by following closely on a laboratory scale the directions of the manufacturers. These dyeings were subjected to the usual tests to show the effect of sunlight, of dye-fading electric lamps, of washing and rubbing, of acid, etc. These test samples, more than 4,000 in number, were mounted on cards. They were much used in conferences with representatives of the War Department.

Dye Making.

A great deal of time was devoted to the preparation of about 30 carefully purified dyes. This was done in connection with the projected development of a comprehensive method for the identification and analysis of dyes by spectroscopic measurements. Commercial dyes can not be used to obtain the fundamental data, because they are rarely simple, pure substances, but generally contain colored organic impurities. Different salts of metals are also frequently admixed. The optical properties of solutions of these dyes are now being studied by the Bureau.

Mordants.

The bichromate used for mordanting wool colors was becoming scarce toward the end of the war, and experiments were made to ascertain whether it was feasible to use other mordants. It was found, however, that bichromate is superior to other readily available materials for this purpose.

Mercerization.

The mercerized yarns produced by various mills differed greatly. This led to a long series of experiments in order to learn the effect of certain changes in the customary process of mercerizing on the physical properties of the yarns.

Flax Packing.

Many samples of braided flax packing, impregnated with tallow, were examined. The grease content and its nature and the kind of fiber used were determined. Some of the packings contained cheaper fibers than flax, and the lubricant contained paraffin or other cheap materials.

Sizing.

A great deal of time was spent during the past few months in analyzing and studying sizing compounds for use on cotton yarns. Some of these are manifestly far superior to others. This work was preliminary to practical studies in the Bureau's cotton mill.

Camouflage.

Fabrics colored with different dyes may appear alike to the unaided eye when in the sunlight. In artificial light, or when viewed through a colored glass or celluloid screen, they may appear as unlike as red and green.

Samples of fabric dyed in this way and appropriately colored screens were prepared in cooperation with another section of the Bureau. Such fabrics as these dyed green and laid on grass can be used to convey secret signals to friendly aviators provided with suitable color screens, while to the unaided eye they will be invisible even at short distances.

Routine Testing.

A large variety of commercial grades and kinds of fabrics, twine, thread, yarn, waste, packing, and loose fibers amounting to over 4,000 in number were tested. Of this number a fair proportion was received from the General Supply Committee and other Government departments.

Airplane Fabrics.

Special studies were made of the standard airplane fabrics already in use, to improve their serviceability and reliability. After a study of the stresses of flight and stress distributions new fabrics were designed and manufactured. As airplanes became larger and heavier it was necessary to cover the wing with a stronger fabric, and after the study of the stress distribution a change in the construction was recommended and applied. Since the filling carried the larger part of the load when the fabric was applied to the wing in the logical manner—that is, with the warp ends running from the leading to the trailing edges of the wing—little warp was used, thus making the fabric lighter, while capable of doing the same work.

Tautness.

As a result of the study of the behavior of wing fabrics under flight, a tautness meter was designed at this Bureau to investigate uniform methods of application and treatment in securing maximum life of a fabric after it had been placed on the wing. Under the present methods of application of the fabric to a wing, few tests have been made to find the proper initial tension of the undoped fabric, the elasticity of the dopes to obtain the best possible permanency of tautness in the wing fabrics, and their method of application, and no information has been compiled which states accurately when and why a wing fabric should be redoped and replaced.

Numerous readings were taken on wing coverings of planes already in service at McCook Field, Dayton, Ohio. It was plainly shown, as a result of these tests, that the observation of the tautness can be interrupted to show the effect of humidity and temperature on the life of the fabric. A report on this subject entitled, "The Preliminary Report on theMcGowan Tautness Meter, and a Study of the Tautness of Airplane-Wing Fabrics and Dopes," was compiled and distributed to interested military organizations.

Penetration of Dope Correlated with Tear Resistance.

Samples of linen and cotton grade A airplane fabrics covered with different amounts of dope, applied by various methods in order to vary the amount of penetration of dope on the fabric, were received for test at this Bureau from the commanding officer of the Wilbur Wright Field. The test results showed many interesting facts, and the conclusions proved of much value.

Balloon Fabrics.

After developing a standard balloon cloth, an investigation was started in cooperation with the Bureau of Construction and Repair, Navy Department, to increase the life and give better permeability. A number of cloths of various thread counts and weights per square yard have been made up accordingly and are now ready for tests.

Satins.

In the determination of the wearing qualities of clothing a number of specimens of satins were submitted and tested on an abrasion machine recently designed and constructed at this Bureau. Although the machine itself is in its experimental stage, the results and conclusions derived are very interesting and promising.

Banana-Plant Fiber.

At the request of the interests concerned, a series of tests were made on the suitability of fibers taken from the stalk of a banana plant as packing for journal boxes. A quantity of the fiber was obtained and tested both in the laboratory and in the journal boxes of railroad and street cars. Satisfactory service was obtained from the fiber as packing for street cars, but it did not prove as good as the wool waste now in use for packing boxes for railroad use. In both experiments one side of the car was packed with banana fiber and the opposite side with commercial wool waste.

Tests of Baseballs.

At the request of the Purchase, Storage and Traffic Division of the War Department a number of new tests were made on representative samples of baseballs, a large number of which were to be purchased for recreational purposes overseas. A detailed and comprehensive report was compiled and submitted. The method of manufacture, construction, composition, resilience, endurance under wear, and other properties of each baseball were noted and recorded, giving the purchaser some useful information from which to make a logical award for the purchase of the same.

Experimental Textile-Manufacturing Equipment.

The textile manufacturing equipment of the Bureau consists of three units—a small felting unit, by which samples of felts are prepared for experimental purposes, made in such a way and of such materials as may be desired; a complete layout of full-sized cotton machinery and apparatus to make fabrics and yarns within wide limits; and a complete outfit of both full-sized and diminutive woolen machines.

These machines and the necessary accessories are of the latest improved construction and are equipped with the accurate adjustments necessary for the work intended. The reasons for the installation of this equipment are quite numerous. One of the fundamental purposes of the equipment was to aid in supplying the manufacturer of military fabrics with exact specifications of the fabrics then being produced. Those engaged in textile-research work were without exact knowledge of the physical properties of such materials, owing to their inability to obtain the necessary variety of fabrics. The present specifications are based on tests, such as the tensile strength, the weight per unit area, and a few other properties not used universally in all specifications, whereas the requirements pertain more to such qualities as those of heat retention and resistance to wear. The making of a sample fabric in a commercial mill seriously retards production because of the large amount of attendant waste of time and material necessary to operate the machinery properly, with no assurance that the sample produced will give the desired results.

It is certain that it would have been very profitable to have had such equipment at the beginning of the war before the Government had issued contracts for textile fabrics and yarns. To-day the value of such a laboratory is realized when it is considered that the products of the textile industry have never been scientifically investigated. Keen competition is to be looked for in the immediate future. It would appear of essential advantage to the American manufacturer of textiles to know more exactly the factors governing the quality of his output, in order that he may more satisfactorily compete with foreign manufacturers.

Other nations have realized the importance of this project and have already perfected elaborate plans for limiting to their own countries the distribution of information concerning the results of research work.

The Bureau is not alone in this undertaking, inasmuch as the National Council of Cotton Manufacturers of this country, which represents practically all cotton mills in the United States, has pledged its support to the furtherance of the Bureau's work on the investigation of cottons and has offered every cooperation that may be desired.

Cotton.

The schedule or program of research work for the cotton mill is growing rapidly, and it is thought that the work on this schedule will soon be started, as the machine and equipment are in place and in operation. The investigation will be restricted to the making of yarns and fabric from the loom, but, as there are facilities for finishing the products, outside services will be requested when the present program is completed.

Woolen and Felt.

The machinery, and equipment of these laboratories are rapidly being put in working condition, and it is expected that samples of work can be taken off in the near future to be investigated as to their physical and chemical properties in accordance with the research program.

PAPER.

(Testing of paper, physical, chemical, and microscopical; study and development of paper-testing devices; investigation of paper-making materials; standardization of paper; manufacture and development of special papers; study of the processes of paper manufacture; collection of data in connection with the testing and manufacture of paper.)

Routine Testing.

The amount of paper used by the Government departments is approximately 50,000 tons per year, and, as it is necessary for this material to be tested to see that it conforms to the specifications under which it was bought, standard methods of testing paper have been developed. This class of work is called routine testing and consists of chemical and physical tests and microanalysis. The chemical tests employed determine the amount of resin sizing that is in the paper, and the amount of filler and loading that has been added to give the paper bulk, opacity, finish, or surface. The physical tests used include the determination of weight, thickness, and bursting strength, as well as folding endurance and tensile strength for certain classes of paper. By means of selective stains and the aid of the microscope, the properties of fibrous material from which the paper was made can be estimated.

During the year 5,000 samples of paper were examined by these tests, of which 4,213 samples were submitted by the Government departments and 789 samples by public and private interests. A total of 19,545 tests were made on these samples, of which 5,397 were chemical, 9,655 were physical, and 4,495 were miscroscopical.

Paper-Testing Methods.

In the investigation of the properties of paper it is constantly necessary to study methods of testing this material, since the laboratory methods in general use are not suitable to determine certain qualities. It has, therefore, been found desirable to study test methods, and, wherever possible, develop a method that will give a numerical value for the qualities that are being investigated.

The property of paper which makes it possible to write with ink upon it is called "sizing." The sizing quality of paper is generally determined by methods that do give an empirical rating, but which are not very satisfactory for laboratory-research or mill-control work. A method for this purpose which, in its simplest form, is a Wheatstone bridge, used somewhat in recent years, is being further developed. By this method the penetration of water through a sheet of paper is measured by the increasing conductivity to an alternating current, which passes through the paper placed in a cell with an electrolyte. The data so obtained are plotted in the form of a curve, and from this curve the rate of penetration may be determined. It was found necessary to add a balancing cell which would reduce the variation of the test due to changes in temperature. As soon as the new apparatus is complete it is planned to study the curves obtained from tests on papers of varying sizing quality and, if possible, reduce these data to a unit basis.

The testing of the physical properties of paper has been investigated with a view to establishing any relationship that might exist between devices of the same general type and between devices that give an indication of different properties. The properties of paper studied in this investigation were bursting, tensile, and tearing strength. A series of papers were tested for bursting strength by three testing machines, and, although the data are not yet complete, it is indicated that the principle from which each machine was developed is based on experimental data rather than on scientific principles. Similar work was done in connection with tensile-strength testing apparatus, and it was found that there are no machines of American manufacture especially adapted to testing the tensile strength of paper. Since the quality of paper is so often judged by tearing a sheet in both directions, it was thought that a method for obtaining a numerical value for this property should be available. Three types of testing devices for this purpose are being studied—a recording mechanism, an apparatus of the balance type giving maximum strength, and an adapted tensile-testing machine from which a number of readings can be taken and an average obtained. It is felt that a study of this property in connection with formation of the sheet and the quality of the paper will be of considerable help to the manufacturer.

Paper-Making Fibers.

Paper is, in general, a matted structure of fibrous materials, and it is possible to make a sheet of paper out of nearly every kind of fiber. In the development of the art of paper making a great many plants, weeds, grasses, etc., have been studied with a view to using them for the manufacture of paper, and especially the quality of paper resulting from their use. The available data on this subject are scattered, but are of great value. The work of compiling information on paper-making fibers is well started, and its scope is as broad as is consistent with the need of the industry. It includes a bibliography, authentic samples with descriptions, and microphotographs of the structure of these fibers.

The well-equipped photomicroscopical apparatus has been of great value in the study of fibers and has made it possible to obtain permanent records of the shape and structure of these fibers. As illustrations of the use to which this equipment has been put, samples of paper from Germany have been photographed, making it possible to duplicate them; it has been possible to obtain microphotographs of unusual specimens loaned to the paper section; and the study of Mexican hardwoods and other similar material has been undertaken.

Felts Used on Paper Machines.

Woolen felts are an essential part of the equipment of a paper machine and play a very important rôle in the formation and quality of the paper produced. During the war the amount of wool available was greatly reduced, and it was thought possible to substitute a small amount of cotton for a portion of the wool in the felt.

Two felts were tested on the paper machine to determine the effect of the addition of 10 per cent of cotton to one of them. Each felt was run for five days on the paper machine, under as nearly similar conditions as it was possible to maintain. Exhaustive tests were made while paper was being run on the machine equipped with these felts, and it was found that the difference between the two felts was not large enough to affect the quality or the production of the paper. It is planned to investigate this problem further and determine whether felts made a greater percentage of cotton can be used satisfactorily on a paper machine. Since the life of a felt is only from three weeks to three months, depending on the machine, the speed, and the grade of paper, any satisfactory felt that can be manufactured more cheaply would lower running expenses.

Utilization of Waste Cotton Linters.

At the conclusion of the war the War Department had on hand approximately 700,000 bales of " munition " linters available for other uses. " Linters " is a fibrous material which is left on the seed after the staple cotton had been detached. It was thought that this material would be suitable for paper making. At the request of the Waste Reclamation Service and the Industrial Cotton Seed Crushers' Association a series of runs was made on the paper machine to determine the quality of paper obtained. It was demonstrated that the paper made from this material was of good quality, free from dirt, and that such linters were a valuable paper-making material. It is to be noted, however, that the grade of linters used in these runs was "munition" linters and was unusually free from dirt and cinders. To demonstrate the possibility of making paper from cotton linters, the programs of the annual convention of the Interstate Cotton Seed Crushers' Association in New Orleans were printed on paper manufactured from this material on the paper machine of the paper section. Since about 700,000 bales per year of linters can be available for paper making, the value of this product as a raw material for the manufacture of paper is great; and if care is taken to keep the linters clean and free from dirt, a greater amount than this can be used for this purpose.

Paper Bags for Lime and Cement.

The increasing use of paper bags as containers for lime and cement has made it desirable to investigate the properties of paper for this purpose. This work was discontinued during the war, but has been resumed. Representative samples have been obtained, and laboratory tests have been made to determine the quality of paper being used for this purpose. A test machine is being used that gives the stress-strain value of the paper, as well as the stretch under load. It is planned to develop a test that will reproduce the strain on the bag when it is dropped.

Due to the fact that no reliable information is available as to the relative merits of bags, it is necessary to determine what laboratory tests most nearly reproduce service conditions. This will be obtained by correlating laboratory tests, by developing new test methods, and by making service tests. As a result of this investigation it will be possible to define the qualities of paper necessary for bags for this type of work and to write suitable specifications. Manufacturers of paper, as well as the lime and cement associations, are cooperating in this work.

Use of Lime and Limestone in the Paper Industry.

Lime and limestone play an important part in the manufacture of pulp and paper. The war has emphasized the value of lime as a chemical reagent, and it was felt that standard practice in the uses of chemical lime should be developed. A representative of the paper section has taken part in conferences of members of the Government departments interested in lime.

The use of lime and limestone in the pulp and paper industry is being investigated. It is planned to develop specifications for lime for the different industries, standard samples, and laboratory and plant methods of analysis.

In this work, technical committees of the pulp and paper industry will be consulted, and it is expected that the specifications and methods proposed will be accepted and used by this industry.

Unbleached Pulp for Papers.

Chlorine from which bleach and bleaching powder is made was in great demand during the war for military purposes, and it became necessary to restrict the use of this chemical for the bleaching of pulp. It was, therefore, necessary to determine the effect on the color of paper that the restriction in the use of bleach would cause.

At the request of the War Industries Board, 21 runs were made on the paper machine using different proportions of dyestuffs with various unbleached pulps. As a result of the action of the War Industries Board, the amount of chlorine used in sulphite pulp was restricted to 40 per cent of the amount then used; in soda pulp, to 70 per cent; and in old papers, to 35 per cent. The use of chlorine for bleaching rags was restricted to 1 per cent.

Filtering Paper for Gas Masks.

At the request of the Chemical Warfare Service, an investigation was undertaken to determine whether paper could be made in the United States similar to that being made abroad as a protection against "sneeze-gas." Tests were made on a commercial scale at two mills, and it was proved that such a paper could be made on a large scale in this country. Due to changes in the construction of the gas-mask canister, a different type of paper was desired, and 35 runs were made on the paper machine, producing a paper that was suitable for the purpose. It was found desirable to have a convenient method of testing this paper, and for this purpose a gas house was built. This house was so arranged that the gas would be formed in one room, and the paper tested in the next room by means of men wearing masks and breathing through flanges so constructed that the paper would act as a filtering diaphragm. In order to obtain a numerical value for the protection afforded by these papers, an apparatus was installed in the gas house that permitted a record being taken of the concentration of the gas before and after passing through the paper.

Military Uses of Wall and Plaster Board.

During the war the investigation of wall and plaster board was continued from the previous year. Three camps visited at the time of their erection were visited again to determine, if possible, the degree of durability of various makes of wall board. The results of the inspection show conclusively that almost any wall board properly erected will give satisfaction in cantonment construction when the buildings are considered as temporary structures. Many of the buildings were in poor condition, due almost entirely to the poor method of erection. All wall boards will expand and contract under different atmospheric conditions, and this expansion and contraction is injurious if the board is nailed at the edges. Wall board should be nailed along the center and the edges but lightly nailed, and then well stripped with pieces of wood to cover the joint and to allow for the expansion and construction of the board underneath the wooden strips.

In order that further information might be obtained as to the behavior of these boards under service conditions, a questionnaire was sent to most of the military cantonments. For temporary structures fiber wall board was preferred, merely because it was considered quicker and cheaper to erect and because of its greater salvage possibilities. Plaster board was preferred for permanent construction—that is, over five years—because it was considered less subject to changes in temperature and because it makes a warmer building. For hospital use plaster board was preferred, due to its greater resistivity to fire and moisture.

Miscellaneous Information Furnished Public and Private Interests.

Specifications have been developed for a small paper mill for the Siamese Government. Drawings were made of the plan for such a mill, and information was obtained as to manufacturers and prices for such equipment.

Plans and necessary equipment for a paper-testing laboratory were outlined for the Australian Government, in connection with the investigation of Australian hardwoods for the manufacture of paper.

The development of the manufacture of blue-print paper was assisted by tests on 75 samples of this paper for a manufacturing concern. These data are to be correlated with manufacturing conditions.

Considerable assistance has been given the Forest Service in the work of revising the commodity classification of pulp and papers. This classification is used in connection with the collection of data of foreign and domestic commerce.

Further work was done in the development of paper containers for export shipment of saddle soap and grease for the War Department. Another use of paper containers under consideration was a carton to carry machine-gun cartridges. This last was to be a part of a new feeding mechanism for machine guns, by the use of which the belt would be eliminated.

Technical assistance was given the Federal Trade Commission in reference to definitions of paper terms which were claimed by that commission to be cases of misbranding. The terms in question were bond, vellum, parchment, Madras, nainsook, etc.

Miscellaneous information has been furnished Government departments in connection with specifications for paper, the testing of paper, and the standardization of paper. Specifications have been developed for private interests for special papers. Information is being collected continuously on paper testing, paper-making materials, and paper-manufacturing methods. In connection with the information an exhibit is being prepared of papers and paper-making materials.

8. METALLURGY.

[Thermal analysis and structure of metals, heat treatment and its effects 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.]

GENERAL ACTIVITIES.

Cooperation with Societies and Boards.

The following paragraphs give the membership during the past year of the members of the metallurgical division in the several scientific and technical societies of which they are members, and also their relation to various Government boards and committees.

Among the activities of importance may be mentioned particularly that the chief of the metallurgical division served as the representative of the Department of Commerce on the Requirements Division of the War Industries Board. This gave an opportunity for the Department to take an active interest in and be helped in many exceedingly important matters coming before the Government. Another member of the staff was very helpful as adviser in ceramics to the War Industries Board and in framing specifications for enameled ware as a member of the Army Committee on Standardization. Another rendered valuable service as a member of the Interdepartmental Committee on Minerals and their Derivatives and in blocking out and aiding in the manganese conservation program. The committee on light alloys of the National Advisory Committee for Aeronautics did most of its experimental work through the Bureau of Standards, and the results of this have appeared in a series of publications. The relations of the Bureau to the American Society for Testing Materials have been very close, and several members of the metallurgical division have been very active in the committee and aiding in the framing of specifications and in presenting for publication standards and properties of metals. The National Research Council has actively cooperated with the Bureau in several problems, and the Bureau representatives are active on some 11 of its committees. The American Institute of Mining and Metallurgical Engineers is holding a symposium upon pyrometry this fall which promises to be a scientific and technical event of great importance. This has been arranged for very largely by the staff of the metallurgical division. Among the important committees formed by the Research Council during the war was one to make a survey and recommend practice as to the ingot and finishing practices in American steel mills. This work originated in the Army Ordnance in connection with the works practice as influencing the output of steel. At a recent meeting of this committee it was decided, however, not to promulgate descriptions of good practice, although the committee had access to a fund of knowledge on this subject.

During the year the metallurgical staff have cooperated with the following committees and organizations: American Ceramics Society; American Institute of Mining and Metallurgical Engineers; American Physical Society; American Society for Testing Materials; American Welding Association; National Advisory Committee for Aeronautics; National Research Council; Technical Staff of the Ordnance Department of the Army; War Service Association of Manufacturers of Bearing Metals and Solders; War Industries Board; Engineering Standards Committee; Interdepartmental Committee; Society of Automotive Engineers; and International Aircraft Standards Board.

Exhibits of War Activities.

An exhibit of scientific development in connection with the war was held at the Bureau by the American Physical Society which was very largely attended, there being a program limited to war topics. There was also a very extensive exhibit of war developments in physics with entries from manufacturers and Government bureaus. The various sections of the Bureau contributed much to the exhibit.

Committee on Nonferrous Alloys.

The committee on nonferrous alloys has resumed its meetings, and is advising very actively with the Bureau on its experimental program and is of very considerable assistance in aiding the Bureau in outlining its investigations of nonferrous alloys.

Conferences.

Conferences have been held at the Bureau on copper pressure plugs for testing ammunition, and a great many informal conferences have been held on many subjects related to specifications and other phases of the Bureau's experimental work; both testing and research in metallurgy.

Publications in Metallurgy.

The publications by the staff of the metallurgical division include the following, which have appeared during the year:

Effect of Rate of Temperature Change on the Transformations in an Alloy Steel (H. Scott): Bureau of Standards Scientific Paper No. 335; Bulletin of the American Institute of Mining and Metallurgical Engineers, vol. 146, p. 157; 1919.

Protective Metallic Coatings for the Rustproofing of Iron and Steel (Rawdon, Finn, and Grossman): Bureau of Standards Circular No. 80; Chemical and Metallurgical Engineering, vol. 120, pp. 458, 530, 591, 1918; fourth meeting, Annual Report of the National Advisory Committee for Aeronautics.

Microstructure of Flaky Steel (H. S. Rawdon): Bulletin of the American Institute of Mining and Metallurgical Engineers, vol. 148, p. 183; 1919.

A Critical Study of the Ledebur Method for Determining Oxygen in Iron and Steel (Cain and Pettijohn): Technologic Paper of the Bureau of Standards No. 118.

Study of the Goutal Method of Determining Carbon Monoxide and Dioxide in Steels (Cain and Pettijohn): Bureau of Standards Technologic Paper No. 126.

Report of Ladle-Test Ingot Investigation (J. R. Cain and H. S. Rawdon); Appendix of Report of Committee A–1 of the American Society for Testing Materials; 1919.

Heat Treatment of Duralumin (Merica, Waltenberg, and Scott): Bulletin of the American Institute of Mining and Metallurgical Engineers, vol. 150, p. 913; June, 1919.

Constitution and Metallography of Aluminum and Its Light Alloys with Copper and Magnesium (Mercia, Waltenberg, and Freeman): Bureau of Standards Scientific Paper No. 337; Bulletin of the American Institute of Mining and Metallurgical Engineers, vol. 151, p. 1031; 1919.

Mechanical Properties and Resistance to Corrosion of Rolled Light Alloys of Aluminum and Magnesium with Copper, with Nickel, and with Manganese (Mercia, Waltenberg, and Finn): Bureau of Standards Technologic Paper No. 132; Bulletin of the American Institute of Mining and Metallurgical Engineers, vol. 151, p. 1051; 1919.

Comparative Tests of Palau and Rhotanium Ware as Substitutes for Platinum Laboratory Utensils (Gurevich and Wichers): Journal of Industrial and Engineering Chemistry, vol. 11, p. 570; 1919.

Science and the After-War Period (Burgess): Scientific Monthly, February, 1919; Journal of Washington Academy of Sciences, vol. 9, p. 57; 1919.

Conservation of Tin in Bronzes, Bearing Metals, and Solders (Burgess and Woodward): Bureau of Standards Technologic Paper No. 109; Transactions of the American Institute of Mining and Metallurgical Engineers, p. 1742; 1918.

Behavior of Wrought Manganese Bronze Exposed to Corrosion While Under Tensile Stress (Merica and Woodward): Bureau of Standards Technologic Paper No. 135; Proceeding of the American Society for Testing Materials; 1919.

Aluminum and Its Light Alloys (Merica): Bureau of Standards, Circular No. 76; Chemical and Metallurgical Engineering, vol. 19; 1918.

Solders for Aluminum (Merica and Gurevich): Bureau of Standards, Circular No. 78; Metal Industry, p. 500; 1918.

Recent Metallurgical Work at the Bureau of Standards (Burgess): In Blast Furnace and Steel Plant; May, 1919.

Letter Circular on Properties of Light Aluminum Alloys (Merica).

The following are in course of preparation or in press:

The Study of the Deterioration of Nickel Spark-Plug Electrodes (Rawdon).

Notes on the Microstructure of Iron and Mild Steel at High Temperatures (Rawdon and Scott).

Metallography Structure and the Related Properties of Metals; A Revision of Circular No. 42 on Metallographic Testing (Rawdon).

An Electrolytic Resistance Method for Determining Carbon in Steel (Cain and Maxwell).

Equilibrium Conditions in the System Iron Oxide; Carbon and Hydrogen in Relation to the Ledebur Method for Determining Oxygen in Steel (Cain and Adler).

Oxygen Content by the Ledebur Method of Acid Bessemer Steels Deoxidized in Various Ways (Cain and Pettijohn).

Investigations at the Bureau of Standards on Gases in Steel and on Deoxidization of Steel (Cain).

Cements for Spark-Plug Electrodes (Staley).

The Use of a Modified Rosenhain Furnace for Thermal Analysis (Scott and Freeman).

Manufacture and Properties of Light-Wall Structural Tubing (French).

Circular on Alloy Steels (French).

Thermal Critical Ranges of Low-Nickel Steels (Scott).

Simplification of Inverse Method of Thermal Analyses (Merica); Bulletin of the American Institute of Mining and Metallurgical Engineers, vol. 151, p. 1021; 1919.

Tin Fusible Boiler Plug Manufacture and Testing (Gurevich and Hromatko).

Embrittling of Steel by Pickling and Plating (Grossman and Langdon).

Properties of Certain Lead-Zinc Bronzes (Staley and Karr).

Five Foundry Tests of Zinc Bronzes (Karr).

Report of the Pyrometer Committee of the National Research Council (Burgess).

Some Tests of Light Aluminum Cast Alloys (Merica and Karr).

Circular on Nickel (Merica).

Aluminum-Magnesium Mirrors (Waltenberg and Coblentz); for Physical Society.

Metals for Pyrometer Standardization (Burgess and Waidner).

The Testing of Clays for Foundry Uses (Staley).

Metallurgical Tests.

Many of the tests performed by the metallurgical division are of an elaborate nature, oftentimes entail a very considerable amount of experimental investigation, and include all phases of qualities of metals and alloys, as well as determinations of causes of metal failures and of serviceability of metals.

Work for the Ordnance Department of the Army.

As an illustration of the type of work being done in detail for several of the military establishments during the war, the work performed for and in cooperation with the Ordnance Department may be cited as an example. The several experimental researches and investigations are described elsewhere. The very considerable amount of testing performed may be emphasized here, however. The Gun Section of the Ordnance Department provided considerable equipment for carrying out routine tests of gun steel to supplement and explain results obtained in the tension tests of samples taken from gun forgings and to show the heat treatment suitable for controlling the microstructure of large guns in forging. Examinations show that the heat treatment of gun forging has been, on the whole,

142289—19——16

satisfactorily carried out and that the inferior properties encountered are generally due to the nonmetallic impurities. Similarly, a systematic series of tests was made on 3-inch brass cartridge cases, representing the product of several manufacturers, which were studied by various methods. A general study of the defects in slugs intended for the manufacture of shrapnel cases was made, as also examinations of copper rotating bands, and a great many samples of failed metals for ordnance purposes.

Testing.

The items formally entered as tests are summarized in the accompanying table:

	Heat treatment and thermal analysis.		Metallographic (including physical, chemical, and corrosion tests.)				Fusible plugs.	Miscellaneous.	Grand total.
	Irons and steels.	Nonferrous metals	Irons and steels.	Aluminum alloys.	Brass and bronze.	Other metals			
For the Government:									
Bureau of Standards	31	4	79			13			127
Council of National Defense	8								8
Emergency Fleet Corporation			1			1			2
Navy Department	1					2		6	9
Panama Canal			8			9		2	19
Patent Office	1								1
Steamboat-Inspection Service							498		498
War Department	21	2	134	4		5			176
War Industries Board	1								1
Coast and Geodetic Survey					1				1
Total	63	6	222	4	1	30	498	8	842
For the public	3		3		2	8		6	22
Grand total	66	6	225	4	3	38	498	14	864

Correspondence.

The metallurgical division carries on a correspondence on a great variety of subjects concerning metals. A typical list is that for the month of February, 1919, as follows: Treating black-iron plates and rods; characteristics of boiler plugs; formulas and specifications for brasses, bronzes, and Babbitt metals; zirconium steels; heat treatment of instrument diaphragms; report to Quartermaster Corps on tests of china and porcelain ware; methods of porcelainizing; comparative merits of nickel chromium and nickel steel for resistance wire; porosity in metals; cracks in enameled metals; solder aluminum joints; car-wheel accidents; metallography of aluminum; publication on aluminum alloys; properties of zinc sheet; steel castings by electric furnace; deteriorations of coatings on copper wire; tests for sharpness; railroad bearings; heat treatment of steel; effect of temperature on strength of bronzes; aluminum-casting alloys; use of uranium; properties of zirconium; supply of invar; stainless steel; corrosion of aluminum by lead; recalescence points of steel; alloy steels; aging of brass; collapsible tubes; noncorrodible steels; pure nickel; Kermat nickel; enameling; hardness of copper; new bronzes; metal for valves; specifications for nails; annealing of phosphor-bronze wire; identification tags; Meinheim-chamber furnace system; gases in steel; cooperite and stellite; literature on steel, iron, and bronzes; heat treatment of rivets, bars, and springs; alloying and refining of gold and platinum; Monel metal; thermal analysis standards; characteristics of high-speed steels; oxidation of brass; the recovery of copper from shell cases; utilization of scrap aluminum; practical welding; copper-lead alloys; manufacture of magnesium; tin-lead alloys for coating copper; drawing of aluminum sheet; metals for ship construction; core oils for foundry sands; small gas crucible furnaces; heat-treating equipment; acid-proof iron alloys; manufacture of tin foil; copper-bearing metal; transformation-points recorder; properties of magnalium; furnace fire bricks; open-hearth special steels; bearing metals for tractors; standard tests for bearing metals; bario metal; substitution of aluminum alloys for instrument brass.

Problems of Military Interest.

The Bureau has developed very close relations with several of the technical military establishments, including branches of the General Staff, the Army and Navy Ordnance Bureaus, the Aircraft Production, the Corps of Engineers, the Signal Corps, and the Quartermaster's Department. In particular, and as illustrative of the type of work in cooperation, may be given a statement regarding some of the problems with which the Bureau is working in cooperation with the technical staff of the Army Ordnance which maintains several men at the Bureau for work on problems in which they are interested.

Test-Bar Fractures.—The Ordnance Department had accumulated a very considerable number of fractured test bars as a result of an examination of many thousands of samples of steel, and it was thought desirable to make a statistical and systematic study of the fractures produced in tension, methods of photographing, and an explanation and description of the various characteristic features by relating them with the structure of the tension bars. The aim is to embody the results of this work in the form of a manual which may be furnished to inspectors.

Hardness of Brass Cartridge Cases.—Another problem is the investigation of the hardness of brass cartridge cases by means of the micro-Brinell-hardness machine developed by the Ordnance Department during the war. The hardness study will be supplemented by a study of the microstructure of the material, determination of mechanical properties, mainly in tension, and their behavior as regards corrosion cracking. The aim is to supplement the various descriptive tests now made of brass cartridge cases. A considerable amount of work was also done by the Bureau in the examination of cartridge cases during the war, for the purpose of finding the effects of various methods of manufacturing upon the properties of the finished material and with a view to aiding the Ordnance Department in its inspection and specification service.

Machine-Gun Erosion.—A systematic study of this subject is being made from the metallurgical point of view, including the preparation of a considerable number of special steels, determination of the interesting physical properties, and the ballistic tests, which last are being conducted by the Ordnance Department itself.

Copper Crusher Gauges.—At the request of the Society of American Manufacturers of Small Arms and Ammunition and of the Ordnance Department, the Bureau has been actively engaged in the preparation of specifications for copper crusher gauges for testing ammunition and standardizing the method of use. A considerable amount of work has also been done on the characteristics of the copper crusher cylinders, particularly as related to their properties under various conditions of annealing and as dependent upon their conditions of precompression, and includes a study of the resulting errors. Several conferences have been held, and it is expected shortly to close this subject.

Centrifugal-Steel Castings.—It was considered desirable to study the properties of ingots cast by the Millspaugh centrifugal method. This method produces an ingot of hollow cylindrical form, and it was thought that there would be a considerable saving of material, labor, and time in the manufacture of cylindrical steel appliances. If the method warranted, it was hoped to be able to substitute cast or heat-treated cast material made by this centrifugal process for forged pieces. The castings submitted for examination were a miscellaneous assortment of four of several chemical compositions and cast under various conditions, but none of the cylinders being cast strictly in accordance with specification requirements for ordnance material. Very interesting and promising results were obtained.

Segregation of the elements—carbon, sulphur, and phosphorus—appears to exist only radially and is confined mainly to a very thin layer of the inner zone, but exists also slightly in the outer zone. Nickel also appears to segregate somewhat, following the carbon. The maximum carbon segregation found amounted to 0.09 per cent in a steel containing 0.66 carbon and nickel 2.2 per cent. Blowholes appear only in the inner segregative zone. The density across a section is practically constant; tensile and shock tests show in general greater strength and elasticity, but less ductility in tangential than in longitudinal directions. This method of casting develops very slight internal stresses. By suitable heat treatment the physical properties of steel cast by this method compare very favorably with forged material of the same composition. The metal of the casting is clean and sound and its microstructure better than in ordinary types of steel casting.

Magnesium Aluminum Alloys for Mirrors.—The Signal Corps and the Corps of Engineers were much interested in the development of a light metallic mirror material of high-reflecting power, and it was desired, if possible, to realize mirrors of diameter up to 6 feet. The Bureau undertook the investigation of aluminum-magnesium alloys for mirrors, and although it was found impracticable to build such large mirrors it was found that the compound Al_3Mg_4, containing 50 per cent magnesium, gave a reflection of 85 in the blue and 93 in the red and that this could be made mechanically satisfactory by a vacuum melting and heat treatment. Although this alloy resists action of dilute acids and alkalies much more than any other AlMg alloy that has come under our observation, it is not recommended where permanency is of prime importance, as some of the samples showed evidences of slight contamination after standing several months in the laboratory.

Corrosion of Aluminum Alloys.—One of the problems in which the National Advisory Committee for Aeronautics and also the Navy Department were greatly interested is the effects of corrosion, particularly under sea-water conditions, on aluminum alloys such as those used in airplane manufacture. A systematic program of experiments and exposure tests have been started and is still under way. A number of the alloys covered with various protective coatings, together with unprotective sheets, are being exposed to the action of the atmosphere and sea water at three widely differing latitudes to determine the best alloy and coating to be used in seaplane construction.

Steel Helmets for the United States Army.—Some work was carried out for the National Research Council in connection with certain problems arising in the manufacture of steel helmets:

(1) To determine whether heating up to quenching temperature in the heat treatment of helmets following the pressing operations was sufficient to remove the stresses set up during the pressing. The average results of tests showed that heating of test pieces of helmet steel to 825° C. and cooling quickly in a furnace reduced the amount of stresses by about 60 per cent, while those test pieces heated to a like temperature and cooled slowly in a furnace showing a reduction of some 73 per cent as compared with the amount of stresses found present in the test pieces which were not heat treated; that is, in the original or pressed condition.

(2) Determination of length of time needed to hold helmet steels at the quenching temperature to get full hardening on quenching. Helmet steels of 11 compositions were also examined to determine their critical ranges in connection with the development of tests for determining resistance to deformation and penetration.

Effect of Prolonged Annealing High-Silicon Cast Iron (Duriron).—The Inspection Division of the Ordnance Department, which was interested in the use of noncorrodible iron of the type of "duriron" (cast iron of the approximate composition—total carbon, 1.18 per cent; graphite, 1.09; silicon, 13 per cent)—requested the Bureau to determine the possibility of any changes in composition upon continued heating. The examination showed that continued heating for as long as 50 hours at 1,000° C. produced no essential change either in structure or composition.

Horseshoe Nails.—At the request of the General Engineer Depot, United States Army, an examination was made of nails representative of most of the manufacturers of this type of material, with the aim of drawing up specifications. The examination showed a rather wide variance in the type of steel used (0.07 to 0.20 per cent carbon) in the process, some being hot forged, others cold-stamped. A simple type of impact test using a notched specimen was recommended for determining the relative merits of different types of nails.

Deterioration of Nichrome Castings Upon Heating.—The attention of the Bureau was called to this problem by the Chemical Warfare Service. The large nichrome castings in the form of tubes used for the production of charcoal for gas masks deteriorated rather rapidly in service, becoming weak and brittle. The examination made of the material showed that, contrary to the opinion expressed by other investigators of this problem, the deterioration does not consist in the formation of a carbide by interaction with the charcoal. On the other hand, the carbide normally present in the nichrome is removed. An intercrystalline brittleness, apparently identical with that of nichrome wires upon continued heating, is produced, the exact nature and cause of which have not yet been determined.

The Relative Cutting Properties of "Cooperite" and "Stellite."—At the request of the Bureau of Ordnance, Navy Department, a test was undertaken to show the relative cutting properties of the two alloys "stellite" and "cooperite." These two alloys, though quite different in chemical composition, have very similar mechanical properties; they are very hard and able to "keep an edge" at a rather high temperature. They are used, particularly stellite, quite extensively to replace and supplement high-speed steel tools for cutting. Cooperite is essentially an alloy of nickel and zirconium with appreciable amounts of iron and silicon. Stellite, which is manufactured in several different grades, is a rather complex alloy, the essential elements of which are cobalt, chromium, tungsten, and molybdenum.

The series of service tests made showed that cooperite is but slightly inferior to the better grades of stellite. Lathe tools made of cooperite failed after a cut of 4-inch lengths made on a 5-inch round of nickel-chromium steel under the following conditions: Speed, 226 feet per minute; feed, 0.0135; depth of higher speed, 240 feet per minute; the other conditions being the same, but for a length of 8 inches before failure occurred.

Defects in Shrapnel Steel.—At the request of the inspection division, Ordnance Department, an extensive and detailed study of the defects in steel slugs intended for the manufacture of shrapnel cases, as revealed in the fracture by the "nick-and-break" test, was made. This was supplemented by a study of slugs which had been sheared as well as broken by the "nick-and-break," the aim being to show whether shearing could be substituted for the latter method in the work of inspection. The results of the examination, however, did not appear to warrant a recommendation from the Bureau for the proposed change in the method of inspection of this class of materials.

Light Armor Plate.—In cooperation with the Bureau of Mines and the Navy Department the Bureau is studying the properties of special alloy steels suitable for the development of light armor. The majority of these steels contain zirconium, while others contain molybdenum, boron, cerium, etc. About 150 ingots have been made by the Bureau of Mines Experiment Station at Ithaca, N. Y., and have been rolled into plates of three-eighths or one-half inch thickness at the Bureau of Standards. The properties of these materials are being thoroughly examined, including mechanical properties, heat treated and annealed, hardness, resistance to impact, microstructure, chemical analysis, and thermal analysis. In conjunction with the ballistic tests to be made by the Navy Department valuable and useful data will be obtained for the design of light armor plate.

Liquid Forging of Light Aluminum Alloys.—The Morris engineering process was investigated in cooperation with the Naval Gun Factory. This process gives a highly satisfactory alloy for aero-to cast or die-cast metal, being of increased strength and ductility and free from blowholes and other imperfections.

Corrosion of Aluminum Carburetors.—This is a problem in which the Aircraft Production Bureau was very much interested. Its importance lies in the fact that particles of sludge resulting from the corrosion taking place in the float chambers of aluminum carburetors lodged in the atomizers and stopped the flow of gasoline. The relation of the composition of cast aluminum to corrosion is being studied, and various protective coatings are being investigated.

Miscellaneous.—Another problem on which some work has been done is an examination of causes of failure due to excessive stress developed in certain parts of the Browning machine gun; as, for instance, bottom plates which split under impact. It would appear that heretofore an inferior grade of steel has been used for this piece.

The Bureau of Aircraft Production was interested in finding a solder of intermediate melting point. A satisfactory special solder was developed by the Bureau of a melting point of approximately 400° C. Its composition is 40 silver, 40 tin, 14 copper, and 6 zinc.

RESEARCH AID TO MANUFACTURERS.

It is the policy of the Bureau to aid manufacturers in the solution of their technical problems, and the following list of investigations will give an idea of the kind of help that it has been possible to render during the past year. This list does not include all the items of such nature, but those given are typical.

Manufacture of Collapsible Tin Tubes.

At the request of one of the large manufacturers of this class of material, the Bureau undertook the investigation of certain defects which often occur on the surfaces of such tubes. These defects consist of discolorations, which interfere seriously in the use of light enamels on such tubes. The study made of this problem, which included a conference with the manufacturer at the plant, showed that one type of surface stain was due to sulphide fumes, the effect being localized and accentuated at certain spots by traces of acid in the perspiration of the hands touching them. Other surface defects, usually as streaks, were pointed out as due to contamination with free sulphur, some of which occurred in the compound used for lubricating the disks from which the tubes were extruded.

Annealing of Hard Cold-Worked Nickel-Brass.

As part of the study made by this Bureau of metals suitable for diaphragms of various types of aeronautic pressure instruments the behavior of cold-worked nickel-brass, which is used largely for such diaphragms, was examined. In the cold-worked sheets the "work lines" to which the hardness is due are very pronounced. Upon annealing, these "work lines" are gradually erased; heating for 20 minutes at 500° C. is sufficient to remove them entirely. The disappearance of these lines or bands may be taken as an indication of the rate at which the hardness due to mechanical working is removed. Above 500° C. the nickel-brass increases rather rapidly in grain size and becomes soft and ductile.

Copper-Lead Bearing Metals.

Several samples of alloys of lead and copper proposed for use as bearing metals have been submitted for examination. The lead content in some is as high as approximately 50 per cent; for example, in "ulcoloy." Lead and copper do not alloy to any appreciable extent; the resulting mixture of the two elements is a "sponge" of copper the interstices of which are filled with metallic lead. The size of the lead globules, which is dependent upon the rate of cooling and the mechanical agitation, determines largely the efficiency of the metal for use in bearings. The principal objection to the lead-copper bearing alloys appears to be the difficulty of reproducing the structure upon remelting for pouring.

Deterioration of Zinc-Aluminum Die-Casting Alloys.

The behavior of an alloy of the composition—zinc 83.4 per cent, aluminum 15.2 per cent, copper 1.4 per cent—was studied in a series of tests which were chosen so as to approximate the extreme conditions of service.

Immersion in water causes no appreciable change in the alloy, nor does dry heat, at least up to 100° C. Moist heat (100° C.), on the contrary, produces a pronounced swelling of the specimens in as short a time as six days. An increase of 7.7 per cent in one of the dimensions of the specimens occurred in 12 days, and the surface of the allow became covered with "alligator" cracks. Evidently this alloy, which may be taken as typical of aluminum-zinc alloys of high zinc content in general, can not be relied upon for die castings in hot, moist climates.

Sterling Silverware.

The advice and help of the Bureau was requested by one of the large manufacturers of silverware during the past year concerning two different types of defects which appear at times on the surface of the finished article. Though not serious, these imperfections impair the high finish and polish which are desired for this class of materials. One type of spot occurs upon standing, and appears to be due to tiny inclusions of the cyanide bath used for annealing; other discolorations are due to surface oxidation of the copper, which is intentionally added to silver to harden it.

Sharpness Standards.

At the request of manufacturers of razors and cutlery, an attempt is being made to devise methods for measuring and defining sharpness of fine cutting edges. This is practically a new field of research, and there is little or no available or published experience to serve as a basis.

MICROSCOPY AND STRUCTURE.

Protective Metallic Coatings for Rustproofing Iron and Steel.

The results of the Bureau's experience in the study and testing of coated metals, together with a résumé of a study of the available technical literature, have been embodied in Circular No. 80 of the Bureau series. The frequent inquiries for reliable information along this line rendered the circular a necessary one.

The Bureau, in cooperation with a committee of the American Society for Testing Materials, has been carrying out an extensive program on the investigation of the properties and testing methods as applied to zinc-coated metals. An extensive series of exposure tests of such metals is being arranged.

Nickel Spark-Plug Electrodes.

A study of the deterioration of the nickel terminals of the spark plugs used in internal-combustion engines was made at the request of one of the large manufacturers of this type of material. The study was extended to include other types of plugs. The brittleness which results in the electrodes upon usage was shown to be a characteristic property of nickel wire and must be expected to occur to some extent in all types of plugs. Deterioration is much more rapid in some types than in others, due to the stresses to which the wires are subjected while hot. These stresses, in turn, depend upon the arrangement and shape of the electrodes. The results of the study will appear as a Bureau scientific paper.

Cements for Spark-Plug Electrodes.

The use of cements for welding electrodes to spark-plug porcelains has been found to be attended by various difficulties in high-temperature engines such as are used in airplanes. Among these difficulties are promotion of oxidation and destruction of electrode wires by reactions taking place in the cements and between the cement and electrode wires; breaking of porcelain caused by difference in coefficients of thermal expansion of electrode wires and porcelain; and the cracking of cement with consequent gas leakage, due to the same cause. A cement composed of silicate of soda and raw kaolin has been found to give little trouble from chemical action. In order to avoid the difficulties attending the use of any form of cement, the use of a mechanical seal at the top of the porcelain has been tried with promising results.

Special Steels.

As part of the study which is being made by the Bureau of "zirconium" and other special steels, a study has been started to demonstrate the rôle which zirconium and titanium play in such steels in the endeavor to explain the effect of additions of these elements upon the physical properties of the resulting steel.

Corrosion of Nonferrous Alloys.

During the year, at the request of the Navy Department, a comprehensive program for the study of the corrosion of nonferrous alloys (particularly copper alloys) was prepared. The Navy Department was to assist in this work by furnishing materials and in arranging for exposure tests in sea water. Due to changed conditions, the material has not been furnished and the work not started as yet. The subject will be taken up in the near future, however, it is hoped.

Study of "Deep Etching" of Metals.

A study of the deep etching of iron and steel has been started. The aim is to show the influence of the various possible factors—chemical heterogeneity (segregation), physical heterogeneity (variations in crystal size, presence of intercrystalline discontinuities, etc.), and mechanical heterogeneity (internal stresses, etc.). The study of the macrostructure of metals has in general received much less attention from metallographists than the microstructure.

Microstructure of Pure Iron and Mild Steel at High Temperature.

An investigation on this subject has just been completed. Its aim has been to show how much the change in composition of the surface layer, which usually accompanies heating in vacuo, affects the results of tests made to reveal the microstructure existing at high temperatures. The results also throw some additional light upon the nature of the composition change of the surface layer, and also the formation of the surface pattern by which the microstructure is revealed by means of "heat-relief" etching.

"Flaky Steel."

Examinations were made of numerous specimens of defective gun steel and airplane crankshaft stock which showed this type of defect. The defect termed "flake" appears as a shining, coarse, crystalline area in the midst of otherwise sound material. The flake, which may be as large as 1 centimeter in diameter, has the appearance of an intercrystalline discontinuity in the steel and is very often (if not always) associated with steel which is badly contaminated with slag and similar inclusions. "Flakes" reduce the ductility of steel, although the ultimate strength of the material (in tension) is not affected nearly so much. They are particularly injurious in material exposed to repeated stresses. The study of this material is being continued, and particular attention will be given to the effect of forging and heat treatment upon such material.

Pearlite in Steel.

A study is being made of the state of pearlite in selected steels of varying chemical compositions after they have been subjected to diverse heat treatments. This is a continuation of some previous researches of Messrs. Howe and Levy. The experimental work has been practically completed, and this will appear shortly as a bureau publication.

Welding Research.

Several national bodies have been interested in furthering our knowledge of means for improving methods of welding. The Bureau has been working in cooperation with the Electric-Welding Committee of the Emergency Fleet Corporation and later with the Research Committee of the American Welding Association. The metallurgical division has been concerned with such questions as outlining specifications for metallographic examination and experimental study of the relations of structure to brittleness in welds; this is being carried out both on material from American manufacture and material furnished by the British Admiralty. The resistance to corrosion of different types of welds, including solubility of acids, in which it appears that the usual types of joints will not corrode faster than a riveted joint, was also investigated. The investigation will also include the effects of the presence of gases entrained in welds; the identification and rôle of certain constituents considered harmful, such as the nitrides of iron, and the development of nondestructive tests for welds. Incidentally, a considerable number of welds of various types have been prepared for physical tests.

HEAT TREATMENT AND THERMAL ANALYSIS.

During the past year the experimental heat-treating plant has been enlarged. An electric muffle furnace and two gas-fired metal and salt-bath furnaces have been installed, and, in addition, the pyrometer equipment for individual units has been changed to a central-station control. Among the smaller units installed have been an electric salt bath for annealing and an electric tube furnace for use in determining tensile properties of metals at high temperatures. A most important addition has been the construction from designs of the members of the staff of a modified Rosenhain furnace for taking heating and cooling curves. This furnace does away with the necessity of varying the heating current. Changes in temperature of the samples studied are produced by raising and lowering the sample in the furnace kept at constant temperature.

New Method for Thermal Analysis.

A new method for making thermal analysis was developed. The usual practice of recording inverse heating and cooling curves is to record with a chronograph the consecutive time intervals. This involves the use of a relatively expensive apparatus now difficult to obtain. It is also necessary in this method to count the time intervals from the chronograph sheet, a process requiring one or two hours. It has been found that these time intervals could be recorded as accurately and almost as conveniently by two stop watches, which thus serve as a cheap substitute for a chronograph. By this process, also, much time is conserved.

Iron-Carbon Transformations.

Considerable progress has been made in the investigation of the transformations in pure iron-carbon alloys, and the results so far obtained have shown some unexpected phenomena of considerable importance. According to the present outline, this investigation will probably be completed during the coming year. The transformations in pure iron-carbon alloys are of great importance, as they form a basis for determining the effect of the alloying elements used in producing alloy steels, and also in the determination of the effect of impurities normally present in small and varying quantities in plain carbon steels. An accurate knowledge of the position and character of these thermal transformations is also of great practical value, as they form a basis for estimating the temperature of the transformations in steels from the chemical analysis, which will eventually eliminate the necessity for commercial apparatus for this purpose.

A study is now being made of the critical ranges of certain nickel-silicon, armor-plate steels in connection with an investigation of the mechanical properties of these alloys. This work includes the independent effect of both nickel and silicon, and also additions of rare elements in small quantities, on the thermal critical ranges in order that correct heat-treatment temperatures may be estimated.

A study of the effect of other alloying elements added to pure iron-carbon alloys is contemplated.

Magnetic and Density Tests.

As fundamental to the interpretation of magnetic tests on heat-treated steels, a correlation of the magnetic properties of a carbon steel with physical properties and microstructure has been undertaken. Magnetic analysis has recently received considerable attention throughout the country, and it is expected that the results obtained will add considerably to our present knowledge of this subject.

Magnetic tests are also being made on a high chromium steel under varying thermal treatments to determine suitability for permanent magnets.

Density determinations are also being made on a series of alloy steels to determine which are the least susceptible to dimensional changes in hardening.

Mechanical Properties.

To throw further light on the effect of varying heat treatments on the mechanical properties of various structural alloy steels an investigation is now under way to correlate the tensile properties with impact and fatigue values obtained with various machines now in use throughout the country, and also with results obtained from torsion and compression tests. Work on what is probably the most widely used structural alloy steel ($3\frac{1}{2}$ per cent nickel) is now in progress and will be followed by tests on other widely used types.

Tensile Properties at High Temperatures.

There has recently been started, and is now under way, an investigation of the tensile properties of metals and alloys at high temperatures. The practical value of increasing our knowledge in this field can not be described in the limited space available. The first tests planned include determinations of tensile values (including elastic limit) on various grades of boiler plate from room temperature up to about 600° C., bearing on the value of the various grades with reference to interlocal strain in locomotive fire boxes. The results are also expected to throw further light on the relative value of two methods of melting used in the manufacture of such plates. Tests to throw further light on the effect of carbon and various alloying elements such as nickel, manganese, chromium, tungsten, etc., are included in the original scheme, these latter tests being made in cooperation with the Blue-Heat Committee of the Engineering Division of the National Research Council.

High-Speed Steels.

A study of high-speed steels is being made to (1) throw further light on their constitution and properties; (2) to develop a simpler method than now in use for determining the relative value of two steels as cutting media. The methods now in use or contemplated include thermal analysis, whereby heating curves are taken on previously quenched samples, and hardness tests made after hardening and tempering at various temperatures. Cooperation from the mills is expected in this work. During the past year the problem of high-speed steel cutting has been at an acute stage, due to the extreme need for high-speed steel and to the shortage in the tungsten supply. This problem has been treated at the Bureau from the points of view (1) of the development of nonferrous cutting alloys, (2) the substitution of metals for tungsten, and (3) the improvement of high-speed steel forming practice; that is, cast versus wrought tool.

The Bureau has had the opportunity of carrying out tests on several types of product, including cast high-speed cutting tools which in test have shown cutting properties equal to the best wrought tools of similar composition. The extension on a large scale of the use of cast tools will work great labor and material saving and will result in lowering the cost of working metals. One of the special products studied has been cobalt-chrome tool steel, samples of which were submitted to elaborate tests and found inferior to the better grades of tungsten steel for high-speed tools. As a lathe tool it gave the best results when used for tools in which the cutting edge was not in continuous contact with the material being cut, as is the case with milling cutters. It can not be said that a satisfactory substitute for tungsten in such tools has yet been found. Besides these performance tests an investigation has been in progress on the general problem of the constitution and theory of the much-discussed high-speed steel and its "red" hardness. Data on several of the physical properties and microstructure of this steel, as affected by various heat treatments, have been collected, and seem to answer many of the questions involved.

Gauge Steels.

An investigation of the most suitable steels and treatments for the manufacture of precision gauges, resulting from work originally carried on for the War Department, is now in progress. The work includes determination and comparison of resistance to wear, permanence, resistance to corrosion, soundness, expansibility, and economy under varying thermal treatments. It is expected that this investigation will be completed during the coming year.

Metal Diaphragms.

Elastic lag and hysteresis are serious sources of error in the metal diaphragms and springs used in aeronautical instruments, such as altimeters and air-speed indicators. An investigation is now in progress to determine (1) the exact nature of these factors and (2) to develop diaphragms and springs which will minimize and possibly eliminate these effects.

Diaphragms and springs of various metals and alloys under varying thermal treatments have been, and are being, subjected to various types of loading in order to obtain a comparison of their elastic properties, and also to determine the best metal for such conditions of service, thereby improving the precision of these instruments. Material advance is expected during the coming year.

Of the numerous nonferrous alloys investigated the most promising for the construction of diaphragms is aluminum-bronze with 7 per cent aluminum content. A study is also being made of the hysteresis of steel springs and its elimination. The work done to date on elastic hysteresis leads to the probable conclusion that it is caused by overstrain. The theory has been developed in detail.

Embrittling of Steel by Cleaning, Pickling, and Plating.

This investigation, which is now nearing a close, was started originally in connection with specifications for aircraft parts to determine the harmful effects of pickling, cleaning, and plating in wires, thin rods, and sheets of various grades of steel submitted to several heat treatments. Experiments with the tensile test as a criterion failed to measure properly the embrittling effect produced by pickling. The impact test on notched bars was also investigated, but it was found that no constant results could be obtained. Alternating-stress tests of 0.30 carbon steel show that pickling in sulphuric acid reduces the resistance to fatigue by more than 30 per cent for rods ranging in diameter from one-eighth to three-eighths of an inch. Steel rods three-sixteenths of an inch in diameter and carbon content varying from 0.09 to 0.87 per cent show somewhat corresponding reductions in resistance to fatigue. Analogous results were obtained by the Erichsen test on sheet steel of various thicknesses and hardness. Brittleness gradually decreases at room temperature, but recovery is not complete although hastened by heating. Brittleness caused by pickling appears to be the result of two effects combined: (1) A temporary effect supposedly dependent on hydrogen; (2) permanent effect caused by roughening or etching action of the acid. The effect of plating upon material which has been cleaned, pickled, or sand-blasted has also been studied.

Temperature Measurements in Steel Works.

Opportunity was offered during investigation of steel-manufacturing processes, particularly with respect to uses of manganese, to measure the temperatures of various types of open-hearth and electric-furnace baths, and also tapping and teeming temperatures, in the practice of five steel companies. The results are particularly interesting, showing the remarkable uniformity of the refining temperatures for steel in the open hearth, both acid and basic. The electric furnace practice, in so far as temperature was concerned, was found not to differ materially from that of open-hearth practice. In the five plants examined the bath temperature was found to range in all cases between 1,590 and 1,640° C. Tapping temperatures ranged from 1,540 to 1,695° C., the higher value being for acid castings. Teeming temperatures ranged from 1,485 to 1,575° C.

PHYSICAL PROPERTIES AND MISCELLANEOUS METALS.

Tin Conservation.

Up to the time of the signing of the armistice the Bureau was actively engaged in studying methods of conserving tin. Experimental work was carried on in finding suitable solders, bearing metals, and bronzes containing a reduced amount of tin, and considerable correspondence was carried on with manufacturers and users of these materials. The Bureau also acted in an advisory capacity to the Bureau of Exports of the War Trade Board in matters concerning the use of tin, and also cooperated with the War Service Association of Manufacturers of Bearing Metals and Solders.

Bearing Metals.

An extended program has been drawn up for an investigation of bearing metals. Although they are very widely used, there is little specific data in those works which treat of their properties and behavior, and no standard methods exist for their testing. The program will include physical tests at normal and elevated temperatures of all the commonly used bearing metals, together with actual tests under service conditions. It is doubtful whether much headway can be made during the coming year on the program, however, because of the lack of funds and facilities for carrying on the work.

Corrosion of Brass Under Tension.

Twelve samples of drawn manganese-bronze rod have been exposed to atmospheric and water corrosion, while under known values of tensile stress, for a period of two years. The results to date are published in Technologic Paper No. 135, and show that, if this type of material is subjected to stresses at or above the proportional limit of elasticity, it may be expected to crack and fail in a relatively short time.

Strength of Solder and Soldered Joints.

In connection with the American Society for Testing Materials tentative specifications for solder, it is thought advisable to determine the tensile strength of the various compositions of solders, and also of soldered joints of various metals with several different fluxes.

Gold-Palladium Alloys as Substitutes for Platinum.

The high cost and scarcity of platinum greatly stimulated, especially during the war, the production of "platinum substitutes" for various purposes. Of those intended for use as chemical-laboratory ware no alloy of base metal so far tested has been found suitable. Two alloys of gold and palladium have been placed on the market and have come into more or less general use. These are known as "palau" and "rhotanium."

A series of tests has been carried out to determine the suitability of these alloys as substitutes for platinum in laboratory ware. The tests consisted of the determination of the behavior of crucibles made from the above alloys on heating to 1,100 and 1,200° C. in an oxidizing atmosphere and the effect of the various chemical reagents. The results of tests would indicate that in many instances these alloys could replace platinum very satisfactorily, thus releasing a large quantity of platinum for other purposes.

Fusible-Tin Boiler Plugs and Tin Alloy.

To systematize the testing of fusible-tin boiler plugs, the Bureau has undertaken the study of the effect of small amounts of impurities on the melting point of pure tin. To this end alloys containing small amounts of copper, zinc, lead, and antimony, respectively, were made and their melting points determined. The results of the investigation would indicate that the first addition of all of the above metals lowers the melting point of tin, except in case of antimony, where the further addition of antimony above 0.1 per cent raises the melting point. The results obtained show that, in testing for purity, the simple melting-point test can be satisfactorily substituted for the laborious chemical tests at present used. The study of the effect of combination of impurities on the melting point of tin is at present in progress. The results of the first part of the investigation are in press and are to appear in an early number of the Bulletin of the American Institute of Mining and Metallurgical Engineers.

Storage-Battery Grid Alloys.

Investigation of the properties of antimony-lead alloys for storage-battery grids is at present in progress. The physical properties, such as the melting point, tensile strength, brittleness, and hardness, are being determined on alloys containing from 3 to 25 per cent antimony.

Acid-Resisting Alloys.

In spite of the success already attained with the use of acid-resisting irons in the chemical industries, there are still factors of difficulty to be overcome. The best alloys, so far as their acid-resisting properties are concerned, contain from 16 to 18 per cent silicon, are very brittle, and are so very hard that it is impossible to machine them in any other way than by grinding with high-speed abrasive wheels.

These points are decided drawbacks against their more general utilization, and experiments are under way at the Bureau to improve the physical properties of the metal and at the same time make it malleable and machinable.

Effect of Degree of Reduction Upon Internal Stresses Set Up During Cold Rolling.

This investigation was undertaken with a view of trying to throw some light on the question raised as to the desirability of using many light drafts instead of a few heavy drafts in the drawing of brass condenser tubing and similar materials. The investigation showed the advantages of using many light drafts.

Solidification of Steel Ingots.

In connection with the ingot research some experiments were carried out by means of paraffining wax ingots, made on a small laboratory scale, to determine the effect of rate of pouring and also the temperature of casting upon, (*a*) thickness of ingot walls formed during early stages of solidification, (*b*) height and location of pipe in entirely solidified ingot. The results of this investigation are being incorporated with other data in a paper for publication.

Working of Metals.

Opportunity has been given in the past year to use the new metallurgical equipment for working of metals on several problems of military interest. It is planned to continue a series of investigations along systematic lines on the working of metals to determine for the various operations, and for metals and alloys including brasses and steels of various compositions the best temperature, the proper amount of reduction and the properties developed by this method of working, and the intercomparison, for example, of the metals which have undergone the operations of rolling, forging, and drawing.

Treatment of Pure Nickel.

An endeavor has been made to make ingots of pure nickel without introducing contaminating gases. The metal is melted in a vacuum furnace, and attempts have been made to cold forge. It is essential to remove all oxides; otherwise the ingots will crumble.

Light Aluminum Alloys.

The investigations carried out on light aluminum alloys, both wrought and cast, outlined in last year's report have been brought to a conclusion, and have either appeared in print or are in press. This work was done largely after consultation with the Light-Alloys Committee of the National Advisory Committee for Aeronautics, and includes an extended study of the heat treatment of duralumin; the mechanical properties and resistance to corrosion of rolled light alloys of aluminum and magnesium with copper, nickel, and manganese; the constitution and metallography of aluminum and its light alloys with copper and magnesium; and some tests of light aluminum cast alloys.

RAILROAD MATERIALS.

The work on railroad materials has been resumed, and considerable progress has been made on several of the investigations, including the heating stresses developed in car wheels, discontinuities producing failure in rails, annealing practice as related to cast-iron wheels, investigation of ingot practice and of packing-ring iron for pistons.

Graphitization of White Cast-Iron.

An investigation has been completed on the graphitization of white cast-iron upon annealing. This problem arose in connection with other investigations on the properties and characteristics of chilled-iron car wheels, and in particular the best range of annealing temperatures. This problem was brought to the attention of the Bureau by one of the car-wheel manufacturers. The composition is so chosen and the wheel is so cast that the tread and inside of flange show white iron and the remainder graphitized or gray iron. In order to relieve the stresses set up during the cooling of the wheel under drastic conditions, the wheels are piled in pits while red hot and allowed to cool very slowly. Investigation developed that the highest temperature at which no graphitization of the tread and flange takes place is about 720° C., which is also the maximum annealing temperature for car wheels. Incidentally, observations were made which contribute to the theory of graphitization in white iron.

Investigation of Chilled-Iron Car-Wheel Stresses.

The investigation of stresses in chilled-iron car wheels caused by heat from brake action has been nearly completed. A very large percentage of car-wheel failures are attributed to stresses caused by heating of the tread by brake action, the central part or the hub of the wheel remaining relatively cool. It is the purpose of this investigation to determine and record for adoption the most suitable material and design of wheels to resist stresses of this kind. In this investigation the tread of the wheel is heated by passing an electric current through a circular resistor insulated from the tread. The wheel remains stationary, thus readily permitting the taking of the necessary temperature and strain-gauge readings. Considerable differences have been found in the behavior of wheels differing in design and weight. Several car-wheel manufacturers have cooperated with the Bureau, and it is expected that this investigation will be published shortly.

Packing-Ring Investigation.

At the request of the United States Railroad Administration, the Bureau is continuing an investigation of the cast iron used in locomotive packing rings and similar parts subjected to the action of superheated steam by correlation of several mileage records furnished by the Railroad Administration, and the chemical, physical, and metallographic properties as determined by the Bureau. It is expected to gather sufficient information to formulate a specification for this important material.

Ingot Investigation.

There is practically ready for publication an investigation carried out with the cooperation of one of the railroads and several of the steel companies involving a comparison of several types of ingot and ingot practice, including chemical, physical, and metallographic surface of the ingots, and of blooms and rails made from them. Of particular interest is the comparison of properties and segregation of rails made from ingots of the ordinary shape following three practices common in the United States, and the corresponding properties of rails made from ingots of the Hadfield type with sink head. This investigation, which will be published soon, will include chemical analysis of split ingots, split rails and blooms, sulphur prints, metallographic investigation, tensile, hardness, and drop tests.

Effect of Sulphur and Phosphorus in Steel for Railroad Materials.

During the war it was found practically necessary to permit the use of steel for railroad and other materials containing higher amounts than was considered desirable of the detrimental elements, sulphur and phosphorus. At the request of the Railroad Administration, the Bureau is outlining an investigation of sulphur and phosphorus and the permissible maximum for the various classes of steel. The question has been under discussion for some time, and it appears that the specification-making organizations, such as the American Society for Testing Materials, are lacking in sufficiently exact scientific knowledge to determine in rational terms the fixed limits of these elements in steels for various purposes. This investigation will be carried out in part with the new equipment now possessed by the Bureau and in part with material submitted by steel manufacturers and the railroads. Some work has also been done on the effect produced by varying the amount of phosphorus upon the microstructure and hardness of a low-carbon steel (basic open hearth and acid open hearth 0.12 per cent carbon and from 0.008 to 0.115 per cent phosphorus). They had been cooled down through the range 750 to 600° C. at different rates varying from 5 minutes to 4 hours, the steel first being heated to 900° C. in all cases.

CHEMICAL METALLURGY.

The work of the section of chemical metallurgy during the past year (and previous years) has been concerned mainly with the small-scale production of pure metals and alloys made therefrom. Physical properties of these alloys and metals are studied in other sections of the Bureau. Such activities have necessitated many auxiliary investigations. Among these might be mentioned researches in progress on methods for determining the gases contained in steel. It has been known in a general way for a long time that commercial steels contain appreciable amounts of nitrogen, hydrogen, and carbon monoxide, and these gases are believed to have important effects on the breaking strength and other properties of the metal. Such questions can not properly be studied until reliable methods are available for determining such gaseous impurities and until steels can be made free from such gases or containing known amounts of them. Accordingly the pure metals and alloys are being melted in vacuum furnaces, so that the products obtained are practically gas free. If desired, varying amounts of any desired gas can then be introduced into the metal and the effect studied. Another method for removing gases, or undesirable effects of gases, consists in adding to the molten metal some other metal or alloy which combines with the gases and renders them harmless, or else removes them. Such alloys are called "deoxidizers," and the processes involving their use are called "deoxidation"; such processes are a vital part of all commercial methods of making steel. The study of deoxidation and the use of new deoxidizing alloys has formed part of the working program of the section of chemical metallurgy.

In many cases, unless alloys are made under proper conditions, they are not uniform in composition throughout, and are then called "segregated." Such "segregated" portions are discovered by analyses of portions of the nonuniform metal taken in some systematic way. Many segregation studies of this type have been conducted in the section, especially on alloys containing carbon and manganese. To reduce the time required for such routine determinations, a new method was devised for determining carbon; this method not only is shorter than others in general use, but is more accurate.

Much of this work has been of importance from a military point of view, particularly those phases of deoxidation studies having as one of their objects the conservation of manganese in the steel industry.

The standardization of practice in methods of chemical analysis in the steel industry and of the shape of test pieces used for securing drillings for such analyses has also occupied the attention of the section.

The activities in these various groups of work, as well as in some others, are described in detail in the subsequent sections of this report.

Alloys and Pure Metals.

The equipment for making electrolytic iron, and melts or alloys of it by vacuum melting, has been doubled in capacity. A method has been developed for making pure magnesium oxide by calcining pure magnesium sulphate at 1,100° for long periods. This method produces magnesium oxide at much lower cost than by the acetate method previously used. Large quantities of this purified material are required to make the crucibles used in producing ingots of pure metals and alloys. A considerable number of ingots of pure iron and alloys, principally the manganese-iron-carbon alloys, have been produced during the year. A thorough segregation study of these alloys has been made, and some use has been made of the Brinell hardness machine in exploring segregation.

Pure Aluminum.

The apparatus described in last year's report has been used, but it has been found simpler to supply electrically the heat for maintaining the bath in a molten condition. Due to the extreme fluidity of the molten cryolite, which causes it to leak from threaded or other joints in the graphite, the design of a suitable container that will permit the metal to be tapped is much complicated.

Tests of Phillips' Alloy.

A ferrous alloy called "Phillips' alloy" was submitted to the Bureau by a firm in Attleboro, Mass., which made the alloy from ore obtained locally. It was claimed that this alloy imparted valuable properties to steel. The Bureau made several pounds of the alloy from the ore and had it added to Tropena's converter steel at the Naval Gun Factory. None of the remarkable properties claimed were found in the steel so made.

Method for Determining Gases in Steel.

The electric furnace described in the previous report has been tested and found not entirely satisfactory. Electric furnaces with pure iron, nichrome, and platinum resistors operating in vacuo have also been tried. Some successful determinations have been made using the latter furnace, and it is believed that the furnaces with carbon, nichrome, or iron resistors will be developed to work satisfactorily. A Northrup-Ajax high-frequency induction furnace is now being tested as to suitability for this work.

Determination of Individual Gases.

Methods for determining oxygen—that is, oxides—nitrogen, and carbon monoxide have been especially studied. The direct determination of nitrogen (by absorption with calcium vapors as calcium nitride and determination of the ammonia formed by hydrolysis of this compound) has been further tested with good results. The apparatus necessary for the determination has been still further simplified. The determination of carbon monoxide by fractional combustion methods, using such catalyzers as copper oxide, cobalt oxide, nickel oxide, etc., has given good results, and work on specific absorbing agents for carbon monoxide is now in progress. Three papers dealing with the Ledebur method for determining oxygen in steel have been completed. Technologic Paper No. 118 is a critical study of the method, and shows that it can determine only a few of the many oxides liable to be present in steel and that such determinations require such unusual care and skill as to render the method of doubtful value. A scientific paper now in press deals with certain fundamental sources of error in the Ledebur method and shows that probably not over 75 per cent of the determinable oxides are given by this method. A technologic paper now in press details work in which an attempt was made to determine by the Ledebur method the oxygen content of steels deoxidized in various ways, but no differentiation according to method of deoxidation could be made.

In view of these researches it is believed that the Ledebur method is of little value to metallurgists.

Another method which was found to be without practical value was the Gontal method for determining carbon monoxide and dioxide in steels. The fundamental defects of this method mentioned in a previous annual report (1917) have been confirmed by later work, which is described in Technologic Paper No. 126.

Conservation of Manganese.

Two lines of research initiated during the war are being carried on with a view to economizing in the use of manganese in steel manufacture:

(1) A series of alloys of iron, carbon, and manganese, using pure materials, is being made, and these alloys are to be tested for physical properties in the heat-treated and annealed condition. With these data it is hoped that revisions in specifications for certain steels can be made whereby their residual manganese content can be much decreased.

(2) An investigation is being carried on in cooperation with the National Research Council and others whereby substitute deoxidizers.

such as various combinations of the deoxidizing elements of silicon, aluminum, titanium, and manganese, will be tried for making steel. The steel so made will be rolled and forged in the Bureau's plant and then tested for physical and other properties. A small open-hearth furnace of 500 pounds capacity has been designed and built for this purpose.

Electrolytic Carbon Method.

The Bureau's paper describing this method appears as a technologic paper, and it will also be published in the Journal of Industrial and Engineering Chemistry for September, 1919.

Ladle-Test Ingot Investigation.

The report on this work has been published as an appendix to the Report of Committee A–1 of the American Society for Testing Materials. Arrangements are in progress to continue the work which was interrupted by the war.

Alloy Work.

It is hoped still further to improve the technique of making pure iron or alloy melts in the following ways: (1) By making crucibles by the extrusion process instead of pressing into molds, as now practiced; (2) by melting 25 to 50 pounds of electrolytic iron at a time and forging this to 1½-inch bars, which will then be cut into suitable lengths and used as charging material for small crucibles used in the Arsem furnace; (3) by continuous operation of both Arsem furnaces as soon as another heavy current line is installed; (4) by use of the Ajax-Northrup high-frequency furnace; (5) by operation of more electrolytic baths for making iron; (6) by attempting to drop-forge test bars to shape instead of machining them.

Work on Gases in Metals.

It is believed, as soon as the Ajax-Northrup furnace is operating satisfactorily, that very substantial progress will be made. It is also intended to perfect the design of the resistor furnaces which have already given some results.

Work on Investigating the Deoxidation of Steel.

As soon as the small open-hearth furnance is installed it will be used to melt heats of steel which will be deoxidized with some of the old deoxidation processes, and also with some of the new deoxidizers developed during the cooperative investigation with the National Research Council. Such steels are intended to be tested for rolling and forging properties, gas content before, after, and during deoxidation, and for the usual physical properties.

Production of Pure Aluminum.

Some experiments will be made in the endeavor further to purify commercially pure aluminum by melting it under fluxes of various kinds. Electrolytic experiements with chemical control of bath composition will be continued.

FOUNDRY.

The Bureau's foundry performs two functions, (1) foundry research and preparation of metals and alloys for the investigations of the metallurgical division, and (2) serves as a commercial foundry supplying castings mostly for instrument parts to the Bureau and other Government laboratories. The time of the foundry staff is about equally divided between these two functions. This foundry appears to be about the only experimental one conducted by the Government and is one of the very few experimental foundries in the country. It serves a vast industry, and its possibilities for growth and service are very large. It is hoped that, in the near future, it will be possible to increase both the equipment and personnel to a point where it will be possible to undertake the investigation of many of the more urgent foundry problems.

Government Bronze and Its Substitutes.

In extension of the cooperative work of the Bureau of Standards with the committee on nonferrous alloys there were made up under identical conditions in five foundries a series of test bars of Government bronze (88 Cu, 10Sn, 2Zn) which were then tested at the Bureau of Standards. A previous five-foundry set of tests of this type of metal had shown very considerable discrepancies, evidently caused by differences in test bars and other variations from standard practice. In the second series care was taken to reproduce as nearly as possible identical conditions of operation in each foundry, and an improved test bar was used. The results for two compositions were as follows:

Number of specimens.	Proportional limit.	Tensile strength.	Elongation in 2 inches.	Reduction in area.
		Pounds per square inch.	*Per cent.*	*Per cent.*
88 Cu, 10 Sn, 4 Zn	12, 200	38, 900	25.3	21.0
5 foundries, 30	±1, 600	±5, 250	±5.9	±4.7
88 Cu, 8 Sn, 4 Zn	11, 000	39, 400	32.0	25.0
5 foundries, 26	±1, 650	±4, 200	±7.0	±4.6

At the request of the Navy Department additional investigations have been made of other modifications of the above type of bronze. Of nine variations in composition of lead, zinc, casting bronzes containing 90 per cent Cu, the most satisfactory had the composition of 90 Cu, 6½ tin, 0.5 lead, and 3 zinc. This composition has a proportional limit of 12,200±650 pounds per square inch, tensile strength of 40,700±1,500 pounds per square inch, elongation in 2 inches of 37.6±6.4 per cent, and reduction in area of 34.1±4.5 per cent. Substitution of lead above one-half per cent for zinc or tin and of zinc above 2 per cent for tin was found to have detrimental effects on the physical properties of the castings. Further work on this series of bronzes is being continued, and it is expected to be able definitely to map the system of bronzes containing copper, tin, lead, and zinc over the range of practical interest.

New Melting Equipment.

The metal-melting equipment of the Bureau has been augmented during the past year by the putting into operation of an electric-arc furnace of a modified Herault type, of 600-pound capacity, for melting steel and iron, and by the construction of an electric crucible furnace for melting steel and other alloys, and a small hearth furnace for melting cast iron. The foundry is now in a position to melt any metals or alloys used in the making of castings.

Weathering of Art Bronzes.

A study is being made of the relation of the composition of statuary bronzes to the facilities with which they assume patinas on exposure to weather. A series of such bronzes has been subject to exposure tests for some three years. This work is being carried out with the cooperation of one of the statuary manufacturers and with the advice of distinguished sculptors.

Efficiency Study of Electric Furnaces.

The Bureau has made an efficiency study of one type of electric melting furnace and has made suggestions for the improvement of several types of electric metal-melting furnaces. This work will be carried further, since melting of metals by electricity has become an important factor in the foundry industry.

Several Types of Metallurgical Refractories.

The possession of a number of types of metal-melting furnaces heated by a variety of fuels, gas, oil, and electricity enables the Bureau to collect data on the action in actual service of different metallurgical refractories under various conditions of heating; the metallurgical and ceramic divisions cooperate in this work, the results of which, it is expected, will lead to a more thorough understanding of the properties and adaptability of existing metallurgical refractories and to the development of new ones.

Protective Coatings for Aluminum Castings.

At the request of the Bureau of Aircraft Production of the Army an investigation of various protective coatings to prevent corrosion of aluminum castings is being continued. After a satisfactory coating can be found it will have considerable value for industrial uses also.

Experimental and Practical Castings.

The past year has seen a marked increase in service given by the foundry to the Bureau and the research laboratories of other Government departments in the preparation of a great variety of kinds and types of metal and alloy castings. The value of castings furnished to laboratories was $1,850. Following is a tabulation of the salient points of this service:

Metal.	Castings.	Patterns.	Weight
			Kilograms.
Bronze	684	93	648
Brass	1,738	417	1,896
Al alloy (light)	432	169	554
Al bronze	58	2	23
Cast iron	68	16	240
Lead	5	4	381
Pb-Sb alloy	1	1	10
Copper	6	1	7
Mirror metal	1	1	9
German silver	8	1	1
Total, 1919	3,008	709	3,875
Total, 1918	2,249	516	2,455

Investigation of Light Aluminum Casting Alloys.

This type of alloy is of great interest in the airplane and automobile industries, and the object of this investigation was to discover alloys with improved mechanical properties, the effects of heat treatment, impurities, foundry practice, and their corrodibility. The tensile properties and hardness of a number of light aluminum-casting alloys have been determined, resistance to corrosion compared, and resistance to alternating stresses determined of a few commonly used compositions. It is possible to obtain an alloy containing from 2 to 3 per cent copper, together with 1 or 2 per cent nickel or manganese, or both, which will have a reasonable amount of ductility, and it is believed that an alloy of this type should have commercial value. Mechanical properties suggested for such an alloy are the following: Tensile stress, 22,000 to 25,000 pounds per square inch; elongation, in 2 inches, not less than 5 per cent. The addition of manganese to alloys containing copper reduces, in a marked manner, the ductility, but increases the tensile strength and the hardness. Annealing at 500° C., followed by several days' aging, increases the tensile strength and hardness and generally decreases the ductility. Magnesium appears to increase the hardening effect of heat treatment. The heat treatment of light aluminum castings would seem to have commercial possibilities. The salt-spray corrosion test showed no very appreciable difference between the several compositions in resistance to corrosion. A study of the resistance to the action of alternating stresses of three compositions of light alloys containing, respectively, (1) 8 per cent copper; (2) 12 to 15 per cent zinc, 2 to 3 per cent copper; (3) 1 to 2 per cent copper, $1\frac{1}{2}$ to 2 per cent manganese, showed very little difference, all withstanding 10,000,000 complete reversals at the maximum fiber stress of 7,000 pounds per square inch.

Molding-Sand Investigations.

Methods have been developed for testing sands and clays to determine their fitness for various uses in foundries. In addition to the testing of a large number of molding sands and clays by accepted methods, this work has involved the development of new forms of apparatus for determining the permeability and the cohesiveness of sands and for ascertaining the proper amount of water to use with a given sand. A new and important feature of this investigation is the testing of sands after converting them, by baking, to approximately the condition of sands being used for making castings. These tests are more instructive than tests conducted on sands fresh from the quarry, as has been the custom hitherto.

Considerable work has been done in connection with the recovery of sand from the waste-sand heaps of steel-casting foundries. Tests have shown that it is possible to reclaim for further use a large proportion of the sands now being discarded.

A bulletin on the methods of testing sands and on the recovery of usable sand from what is now considered waste material is now being prepared.

New Type of Volumeter.

A new type of volumeter for accurately measuring the volume of bodies of irregular shape (such as sand, etc.) has been devised and its limits of accuracy derived. The principle of the apparatus is the displacement of a liquid upon immersion of the solid and the measurement of the amount of liquid displaced by noting the rise of liquid in a long slanting tube of small bore. The advantage of this apparatus is that it is very rapid in operation and measures volumes to 0.01 cubic centimeter, while the accuracy obtainable with other types of displacement volumeters is limited by the size of one drop of the liquid used, approximately 0.05 cubic centimeter. This apparatus has many possible applications in testing and research work.

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.)

Standardized Clay Tests.

Considerable work has been done during the past year in cooperation with the committee on standards of the American Ceramic Society in its endeavor to establish uniform methods for the testing of clays. Check determinations have been made and several devices designed for use in this connection.

Refractories.

The general subject of refractories has received continued attention. Definitions covering the general requirements of clay refractories have been proposed and adopted as tentative specifications by the American Society for Testing Materials. Work is in progress on a modified method of determining the softening point of refractory materials.

Tests involving the estimation of the softening point, resistance to load, and the chemical composition have been made throughout the year for the Panama Canal, several navy yards, and other departments of the Government.

Two technologic papers dealing with the subject of silica refractories have been published.

Considerable work has been done in cooperation with three manufacturers dealing with the development of improved blocks for glass-melting tank furnaces. The importance of this subject justifies vigorous effort. The results so far obtained are encouraging and indicate that the study has been pursued on sound principles, but trials on a large scale are required to verify the facts so far ascertained.

A very satisfactory white furnace cement to be applied upon the exterior of furnace walls or to be used as a mortar has been developed.

Light-Weight Refractories.

The new type of refractory proposed by the Bureau last year, combining light weight, porosity, good heat-insulating quality, and high refractoriness, has aroused considerable attention, with the result that several companies have undertaken its manufacture. There is every reason to believe that this type of material will find application in connection with marine-boiler installations, furnace crowns, kiln blocks for terra cotta, and other wares.

Refractory Porcelain.

Further progress has been made in the production of the heat-resisting material known as Marquardt porcelain, formerly imported from Germany, and it has been found possible to produce pyrometer tubes over 7 feet in length. A technologic paper on this subject is in course of preparation, and a similar contribution has been submitted to the American Institute of Mining Engineers to be read at the September meeting, 1919. Assistance has been rendered to three plants engaged in the manufacture of Marquardt porcelain. The necessity of firing to a temperature of not less than cone 16, and preferably 18, has been pointed out.

Sillimanite Refractories.

Tubes and other shapes of commercially pure sillimanite ($Al_2O_3.SiO_2$) composed of 102 parts of anhydrous alumina and 258 parts of kaolin have been made and have proved satisfactory.

American Crucible and Glass-Pot Clays.

A technologic paper dealing with this subject has been submitted for printing. It comprises a careful study of the physical properties of a number of high-grade domestic clays compared with two well-known German clays. At the same time the principles involved in the construction of crucible and pot bodies are discussed.

Porcelain Glass Pots.

The porcelain and semiporcelain pots worked out for the melting of optical glass have been thoroughly tested out in several hundred melts and have proved very successful. The best porcelain composition has been found to be as follows:

	Per cent.
White-ware bisque, through 10-mesh sieve	48
Tennessee and Kentucky ball clays	23
Kaolin	24
Feldspar	5
Total	100

The white-ware bisque is waste material from earthenware and wall-tile plants.

Casting Process.

The process of casting glass pots and other heavy clay products has been steadily improved and has been extended to the making of closed pots. Further developments are under way in cooperation with two manufacturing establishments.

Study of Spark-Plug Porcelains.

The results of a large number of experiments with 195 porcelain compositions have been analyzed and described in Report No. 23, Aeronautic Power Plants. Similar reports will be published as a Bureau publication and in the Journal of the American Ceramic Society.

One of the best porcelains, showing high electrical resistance at a temperature of 690° C. and good mechanical qualities, has the following composition:

	Per cent.		Per cent.
Georgia kaolin	10	Calcine No. 19	40
Florida kaolin	10	Calcine No. 14	20
North Carolina kaolin	10	Delaware kaolin	10

The compositions of the calcines are:

	Calcine No. 14.	Calcine No. 19.		Calcine No. 14.	Calcine No. 19.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Kaolin	56.00	70.20	Potters flint	25.80	
Anhydrous alumina		27.80	Boric acid		2.00
Magnesium carbonate	18.20				

The minimum maturing temperature of this porcelain corresponds to cone No. 16, or approximately 1,450° C. The calcines Nos. 14 and 19 require 1,390 and 1,530° C., respectively, for proper calcination.

The use of this type of porcelain is being extended to products other than spark plugs, where high electrical resistance at elevated temperatures is required, such as heating devices, insulators for the Cottrell process, etc.

Use of American Clays in White-Ware Pottery.

The cooperative work conducted with the United States Potters' Association in 11 plants at East Liverpool, Ohio, has been completed. The object of the investigation was to make pottery entirely from American clays under commercial conditions. It has been shown that tableware of excellent quality can be made from domestic materials. Of the 46 compositions more than one-half proved to be satisfactory.

Terra-Cotta Bodies and Clays.

An exhaustive study of practically all clays and prepared mixtures used in the manufacture of architectural terra cotta is under way and is rapidly approaching completion. The work embraces the study of the porosity and volume changes shown by the materials at different firing temperatures, their mechanical strength as estimated by the transverse test, and their resistance to the disrupting action of crystallizing sodium sulphate. In this manner it is expected to establish the minimum temperatures to which the materials must be fired in order to possess the required strength. At the same time, the peculiarities of the clays and bodies from different parts of the country will be set forth.

Hard-Fire Porcelain.

The elaborate investigation of hard-fire porcelain begun three years ago is approaching completion. More than 300 compositions have been studied with reference to porosity and volume changes at different temperatures, the points of vitrification and overfiring, mechanical strength, tendency to deform, coefficient of expansion, and other physical constants. Several thousand pieces of tableware, plates, cups, and saucers have been glazed and fired. It is believed that this work will shed much light upon aspects of hard-fire porcelain manufacture which have been overlooked, and will contribute toward placing our knowledge of this snbject on a firmer basis.

Several one-fire porcelain compositions have been developed with a pleasing glaze which have been applied successfully in several potteries.

Cooperative work has been done also in connection with the manufacture of hard-fire porcelain for use in the textile industry.

Clay Tests.

Approximately 300 tests of clays, fire bricks, feldspar, flint, whiting, and other ceramic materials have been made for Government departments and the public.

Scientific and Industrial Cooperation.

Cooperation is being maintained by the Bureau with many firms and individuals with reference to industrial problems, both by correspondence and consultation.

A large amount of work is being done also in cooperation with the scientific branches of the Government, the National Research Council, the American Ceramic Society, the National Terra Cotta Society, the United States Potters' Association, the Refractories Manufacturers' Association, the American Society for Testing Materials, the National Brick Manufacturers' Association, etc.

Equipment of Ceramic Division in Industrial Laboratory.

The contracts for the construction of new furnaces and kilns have been let, all of the machinery and apparatus purchased, and the installation of the equipment begun.

Enameled-Metal Products.

A section devoted to this branch of industry has been formally organized and has begun its activities in a vigorous manner. Two technologic papers dealing with the principles of iron enameling are being printed. The researches under way are concerned with difficulties encountered in the manufacture of enameled cast iron and steel products.

Several enamels adapted for application on copper have been worked out, which replace similar compositions formerly imported from Germany.

Zircite Refractories.

Fire bricks made from zircite ore cemented by means of ball clay have been made for the Washington Navy Yard.

Zinc Spinel.

A study has been made of the proper temperatures required to calcine mixtures of zinc oxide and alumina to form crystalline $ZnO.Al_2O_3$, which is used as an opacifier in enamels and glazes, replacing the expensive tin oxide. Likewise, the use of different sources of zinc oxide and alumina, such as zinc carbonate and hydrated alumina, were investigated.

Tennessee Ball Clays.

The effect of washing Tennessee ball clay, represented by 15 samples, has been studied by determining the residue left on the lawn, the volume shrinkage, and the strength of the dried clay, the color and shrinkage of the fired material. The purpose of this work was to show whether refining of the material by washing is justified.

Investigation of Brick Piers.

The complete data of this investigation, covering the discussion of the results of tests on 50 piers $2\frac{1}{2}$ by $2\frac{1}{2}$ by 10 feet high, has been published since the last report. The demand for this report has been so extensive that it has been necessary to issue a second edition. An abstract of this investigation was presented in the last report.

Investigation of Strength of Hollow-Tile Walls.

Material Used.—The tiles used in the construction of the walls were furnished through the courtesy of the National Fireproofing Co. The results of determinations of the physical properties of the tile have already been published in Technologic Paper No. 120, the specimens being from an Ohio plant. The data obtained were chiefly the compressive strengths and absorption properties. About 250 tests were made. The strength, moduli, and hardness results were correlated with the results of absorption tests. It was found that the strength of the tile, when tested on ends, averaged about 7,500 pounds per square inch of net cross-sectional area, with a variation from 4,500 to 12,000 pounds per square inch between the minimum and maximum results obtained for the series. The compressive strengths and moduli of elasticity varied approximately inversely with the capacity to absorb water. The absorption varied from 4.4 to 10.9 per cent, with an average of 8 per cent. Through the joint cooperation of committee C–10 of the American Society for Testing Materials similar tests were conducted by various laboratories with different geological locations. The ceramic properties of the clay influence the behavior of the finished product and depend on the location. Through the correlation of the results with those of the other laboratories—all data being selected in accordance with the same general program—it is believed important information has been furnished for writing building-codes specifications as regards this commodity.

Description of Walls Tested.—There were 32 walls constructed for test purposes according to the following specifications: The walls were 4 feet wide by 12 feet high and thicknesses of 6, 8, and 12 inches, depending on the dimensions of the tile. The tile for 24 of the walls were selected from an Ohio plant and those for the remaining walls from the Perth Amboy (N. J.) plant of the National Fireproofing Co. The compressive strengths of the walls were determined with the flues running vertically in one series of tests, in another with the flues running horizontally, the load being applied concentrically with the axis of the 10,000,000-pound testing machine. Similar tests were carried out to determine the effects of applying the load eccentrically to approximate the behavior of joists and floor loads. Further tests also were conducted on the strength and absorption of the individual tiles.

The results obtained are, in brief, as follows: The average loads for the 6, 8, and 12 inch walls of Ohio tile, flues vertical, under concentric loading, were 297, 408, and 543 in thousand-pound units, respectively, and about half these values when the flues were placed horizontally. The Perth Amboy 6 and 12 inch walls withstood much lower average values—that is, 137 and 241 in thousand-pound units, respectively—when flues were vertical and 42 and 70 in thousand-pound units when horizontal.

There was a marked reduction in the strength of the walls as a result of eccentric loading, and in several cases the failures were local at point of loading, in which case the walls were retested under concentric loads, as before.

It was originally the intention to carry out the tests in accordance with the program covering geographical districts, so as to be representative of the entire national output. War conditions made this impossible on account of the lack of transportation facilities. But, since there are now numerous results of tests of tile from different districts tested in concert, it may be assumed that the ratio of the strengths of single tiles to those of walls will be proportionately the same in the various districts as has been found for Ohio and New Jersey.

All the tests have been completed, and the results are being prepared for early publication.

Architectural Terra Cotta.

The study of the properties of this material has been continued during the year with very gratifying results. More attention was paid to the examination of the material in service on buildings for various periods of time. Two very striking types of failures were encountered, both due to lack of knowledge of the proper use of terra cotta. The first type is that where the glaze is forced away from the body. This is apparently due to improper protection of the unglazed portions from contact with moisture, such as "backing up" free standing work with soft brick, or lack of flashing or waterproofing edges or joints of this type of work. The second type is due to improper methods of attaching the terra cotta veneer to the structure and is shown by actual crushing of the terra cotta. These examinations force one to the conclusion that too many failures are due to a lack of proper knowledge of the use of otherwise satisfactory materials. This applies to other veneers, especially stone, which is used so much on the exterior of lower floors of structures Both granite and limestone were found which had failed either in compression or shear.

The laboratory part of the work consisted in making test pieces for absorption, artificial freezing, and transverse-strength determinations from the various clays and bodies used by the majority of the manufacturers of the country. These test pieces were burned at seven different temperatures. With the collation of the data obtained from these, a final report will be prepared during the coming year, covering all the work done by the Bureau on this interesting and valuable decorative material.

Fire Tests of Concrete Columns.

In this investigation, 28 full-sized building columns of reinforced concrete have been made, 25 have been subjected to the combined fire-and-load test, and 7 have been tested cold, in compression, in the 10,000,000-pound testing machine. A complete description of this work will be found in the report of division 3.

Determination of Laws of Earth Resistance.

This research was inaugurated in cooperation with the soils committee of the American Society of Civil Engineers and has been briefly discussed in the last report. The matter has already been given considerable attention by the Bureau in the field of electrolysis mitigation and the related problems in soil resistivity. The present investigation has dealt entirely with the corresponding problems involving the laws of mechanical resistance to strain as a result of the presence of engineering structures in earths—piers, foundations, piles, retaining walls, etc. It has been the aim to ascertain the laws which condition or control engineering practice and to give the proper dynamical interpretation of these laws in accordance with the accepted principles of physics. It has been found experimentally that the behaviors of soils are conditioned by their structures. This fact has largely been ignored in soil analyses. It is therefore necessary to conduct fundamental investigations to determine these structures and the laws of transmission of matter, energy, momenta, stress, or other entities as influenced by them. The cooperating committees have given attention primarily to the classification of soils, the proper hypothecation of structures in conformity with statistical mechanics, the devising of apparatus for field and laboratory measurements, and the conducting of individual tests to determine the actual properties and behaviors of a great variety of soils. It has been found thus far that the problem of soil behaviors admits of a complete scientific statement and direct correlation with other physical science. In several cases the mechanical behaviors have been found to correspond very closely to analogous results found in the related problems in the various branches of physics. In other cases the predictions and contentions of scientific investigators as to the impracticability and irrationality of the older theory of earth resistance, as previously formulated, are sustained by experiments.

On account of the surmounting of certain mechanical difficulties which have been encountered from time to time in experiments and the labor involved in the dynamical interpretation of the various data it has been impossible to complete the final report at this time. Several reports have been published by the soils committee of the American Society of Civil Engineers, which contain the results of the preliminary and earlier experiments made by the Bureau. The final report on the investigation is being prepared for publication.

General Tests of Structural Materials.

The following tests not classified in reports of researches have been made for various departments of the Government and different manufacturers. These include 57 tensile tests of wire ropes ranging in diameters from three-eighths to 1½ inches, including the preparation of most of the specimens for tests, for use by the Government at the Isthmian Canal; 34 tests of Manila rope ranging in diameters from three-fourths to 4 inches; 1 test of a steel hoisting sling for derricks; 4 tensile tests of sheet aluminum; 4 determinations of the elasticity of special spring steel; and 8 tests of sand-lime brick for compression and bending.

A number of tests were conducted for the underwriter's laboratory, as follows: Determination of the compressive strength of 3 reinforced-concrete columns and 9 timber columns, including moisture percentages; 20 bricks and 100 building tile tested transversely to ascertain the flexural strength.

The following tests were made for different departments of the Bureau of Standards: (1) For the cement section: Four hundred and forty-four transverse tests of 1-inch square bars of sorel-cement flooring material 11 inches long; 297 compressive-strength tests of 6-inch concrete cylinders 12 inches long; 980 similar tests of 2 by 4 inch cylinders of sorel cement; 385 compression tests of 2 by 2 inch cubes of cement. (2) For the fireproofing section: Seven concrete columns 12 to 18 inches in diameter by 9 feet for compressive strength; 133 cement cylinders in compression; 102 cylinders of concrete 6 inches in diameter by 12 inches; tensile tests of 9 steel reinforcing bars. (3) For the ceramic section: Eighty-seven porcelain cylinders 1¼ inches in diameter and 36 1-inch porcelain cubes for compressive strength; 19 transverse tests of clay briquettes and 25 of brick. (4) For the lime section: Fifty-four tests of 2-inch lime cubes and 50 tests of 6 by 12 inch cylinders both in compression.

Inspections of reinforcing steel for the Bennings viaduct were conducted at various steel mills for the Commissioners of the District of Columbia by this department.

STATEMENT SHOWING NUMBER AND VALUE OF TESTS AT THE (PITTSBURGH LABORATORY) BUREAU OF STANDARDS. FISCAL YEAR 1918–19.

	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Cement	2,804	$7,924.00			2,804	$7,924.00
Clay products [a]	61	673.00			61	673.00
Miscellaneous	122	936.00	47	$155	169	1,091.00
Chemical	585	2,073.50	1	10	586	2,083.50
Total	3,572	11,606.50	48	165	3,620	11,771.50

[a] In addition to the above, preliminary tests on samples of clay, for which no fee is charged, were made on 39 samples.

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.)

Steady progress has been made in the development of optical-glass manufacture at the Pittsburgh laboratory. New procedures in molding, such as gathering direct from the pot and softening the glass in the glory hole were tried out. The results of the investigations on annealing conducted at the Washington laboratory were applied in the Pittsburgh plant. The melting schedules have been more and more standardized.

The indices of refraction, the dispersion value, the percentage light transmission, the oxide composition, and the batch mixtures of the optical glasses made at the Pittsburgh laboratory are given in the following tables:

OPTICAL PROPERTIES OF GLASSES MADE BY THE BUREAU OF STANDARDS.

Kind.	N_d.	N_c.	N_f.	N_g.	V.	T.
Light flint	1.582	1.578	1.592	[a]1.600	43.6	99.7
Medium flint	1.624	1.618	1.635	1.645	37.0	98.5
Dense flint	1.648	1.643	1.661	1.673	35.0	99.1
Light crown	1.518	1.515	1.523	1.528	59.8	98.8
Barium crown	1.570	1.567	1.577	1.590	58.2	99.0
Dense barium crown	1.610	1.607	1.618	1.630	56.0	96.0
Borosilicate	1.516	1.514	1.522	1.527	61.6	97.8
Barium flint	1.550	1.548	1.560	1.565	52.0	99.5

[a] N_g1, N_d, N_c, N_f, N_g=indices of refraction for D, C, F, G lines, respectively, of the spectrum. V=dispersion; T=transmission.

COMPOSITION OF GLASSES MADE BY THE BUREAU OF STANDARDS.

I. OXIDE COMPOSITION

	SiO_2	PbO	BaO	ZnO	CaO	Al_2O_3	K_2O from K_2CO_3
Light flint	53.9	32.3	....	....	5.0	....	2.50
Medium flint	45.2	44.8	....	....	2.0	....	1.10
Dense flint	39.3	48.1	....	....	4.8	....	2.20
Light crown	66.7	....	10.6	1.5	....	....	3.7
Barium crown	48.0	....	26.5	8.4	2.0	....	4.0
Dense barium crown	39.0	....	45.0	7.0	....	1.00	....
Borosilicate	66.5	....	7.8	2.0	....	....	2.9
Barium flint	58.8	13.7	12.3	2.5	1.0	....	4.0

	K_2O from KNO_3	Na_2O from Na_2CO_3	Na_2O from borax	As_2O_3	Sb_2O_3	B_2O_3 from borax	B_2O_3 from boric acid
Light flint	5.00	1.00	....	0.4	....	....	....
Medium flint	3.00	3.50	....	.4	....	....	....
Dense flint	4.60	....	....	.2	0.9	....	....
Light crown	1.3	10.87	1.43	.4	....	3.50	....
Barium crown	4.0	.15	1.86	.5	....	4.26	0.33
Dense barium crown	2.6	....	....	.4	....	....	5.00
Borosilicate	2.9	7.10	2.70	.2	....	5.90	2.00
Barium flint	4.3	.70	1.00	....	....	1.70	....

II. BATCH COMPOSITION

	SiO_2	PbO	$BaCO_3$	ZnO	$Ca(OH)_2$	Al_2O_3	KNO_3
Light flint	49.1	29.0	....	....	6.26	....	9.50
Medium flint	42.2	41.4	....	....	2.55	....	5.90
Dense flint	36.9	45.2	....	....	4.51	....	9.45
Light crown	56.2	....	11.55	1.24	....	....	2.28
Barium crown	40.6	....	29.05	7.05	2.33	....	7.05
Dense barium crown	32.7	....	48.23	5.91	....	0.83	4.65
Borosilicate	56.9	....	8.88	1.67	....	....	5.81
Barium flint	51.3	11.9	15.94	2.11	1.22	....	7.94

	Na_2CO_3	As_2O_3	Sb_2O_3	Boric acid	Borax	K_2CO_3
Light flint	1.41	0.33	....	....	....	4.4
Medium flint	5.50	.45	....	....	....	2.0
Dense flint	....	.20	0.90	....	....	3.84
Light crown	15.45	.33	....	....	7.23	5.72
Barium crown	....	.40	....	0.47	7.19	5.86
Dense barium crown	....	.33	....	7.35	....	....
Borosilicate	10.60	.18	....	3.30	9.04	5.93
Barium flint	1.22	.33	....	....	3.66	6.38

Colored Glasses.

A series of red glasses covering a wide range of composition have been made with the use of selenium and cadmium compounds and the heat treatment necessary for bringing out the color determined. Similar work has been done also with other colors, it being the intention to develop a complete series accompanied by spectroscopic and other optical determinations.

Washington Glass Plant.

The new melting furnaces, pot arches, annealing and molding ovens have been erected, and the plant is ready for operation.

Work has been begun on the making of disks for large lenses.

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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.]

1. GENERAL.

ORGANIZATION.

During the fiscal year 1918–19 the office division has changed from a war to a peace basis. The Office is organized in 10 sections, and includes also all clerks assigned locally for the office work of the divisions. The sections are designated finance, personnel, publicity, property and stores, mail and files, library, dispatch, purchases, copying (detailed), 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.

During the year the organization has been making steady progress. A systematic plan of charting functions and procedure has resulted in greatly facilitating the handling of the Bureau's business. A simple and novel system of office organization is being perfected, the main features of which are as follows:

Function chart, tabulating all Office functions, grouped into sections of related work.

Process chart for each Office function (about 200 in all), showing actions and action points, diagrammatically tracing the course of action.

Standard practice, describing each step in each function clearly and completely enough to instruct a new clerk or an alternate.

Time standards showing for each function approximately the number of clerk hours required daily.

Office calendar, a schedule of all periodic functions.

Staff assignments, a chart of 12 diagrams showing assignment of staff to office functions.

Arrearage record, showing clerk hours arrearage for each function.

Arrearage adjustment, reassignment of staff to duties and duties to staff upon basis of (*a*) peak and valley loads of incoming work, (*b*) net resulting arrearage after temporary simplification or deferment during peak periods.

Residual arrearage is to be met by (*a*) permanent reduction of routine or more automatic methods, (*b*) transfer of work, or (*c*) estimates for extra help.

Alternate system by which absentee's work is handled by understudies, and during interim needed duties are handled, readjusted, or simplified.

Space.

The growth of the Bureau and the steadily increasing volume of work being handled call for additional space. In fact, the Director's offices, including the central administration, conference rooms, library reference room, and stacks, and the various sections of the Office division will eventually require an administrative building, preferably of the modern office type. It is hoped that plans will be prepared with a view to submitting such an estimate within a year or two. The present offices were designed to be available as laboratories and could be so used. It would be both economical and efficient to have the administrative building equipped with the special facilities required in the varied work of the central offices.

Staff.

The readjustment of administrative salaries generally and of the wages of skilled workers emphasized the importance of providing a suitable scale of pay for the section chiefs in the Office sections and in the general scale of clerical salaries. A recommendation will be made to this effect in submitting the estimates. The equity of equal pay for equal training and experience is becoming recognized and being applied generally, assuming an acceptable standard of quality of work. The clerical work is essential work as important as any other, and the salaries should be commensurate, both to develop ability from the present personnel and to secure new appointees of ability when required. Given mental alertness, interest, and good physique, the necessary training can be acquired in the Bureau for practically all grades of work. Success has been shown in cases which appeared unpromising. Conscientiousness, interest, and esprit de corps are the strongest factors in securing efficient service, and it is believed that the success of the Office work during the past year has been largely due to these qualities in the Office staff.

2. SECTIONS.

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.)

Funds and Disbursements.

The regular appropriations of the Bureau, including the war funds, amounted to $1,266,860. In addition, $479,300 was assigned by the President to the Bureau from the national security and defense fund for special investigations on war problems and to complete laboratories under construction. At the request of several departments of the Government the Bureau undertook special cooperative researches, for which purpose approximately $643,000 was allotted to the Bureau. The Bureau appropriations were also directly reimbursed by about $285,000. The total expenditures during the year amounted to approximately $2,674,160.

Staff.

After the signing of the armistice the accounting staff was reduced by three, although the numerous reimbursements entailed much extra work in rendering the necessary vouchers and following the cases through to final settlement. The assignment of a clerk as "voucher runner" has greatly facilitated the payment of vouchers. Close watch is kept on the location of vouchers within the Bureau to reduce delay at all points along the line. The transfer of the audit staff to the north building temporarily relieved the congestion in the quarters of the finance section.

Office System.

The installation of a special card system and visible index for pay rolls resulted in a quicker and more accurate method of preparing the rolls. The numerous Bureau funds, and allotments within the Bureau (about 250 in all), made it essential to have some quick method of reference. A visible index is now being used for this purpose, and this clearly indicates at a glance the titles and amounts of appropriations, allotments, funds from other sources, etc.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1919, 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, 1919:

Appropriation.	Amount appropriated.	Disbursements.	Liability.	Balance.
Salaries	$432,360.00	$342,545.03	$33,690.28	$56,124.69
Equipment	75,000.00	54,322.44	18,020.05	2,657.51
Repairs and alterations	6,000.00	5,688.11	305.58	6.31
General expenses	50,000.00	18,969.55	28,199.64	2,830.81
Grounds	7,500.00	4,672.18	2,736.40	91.42
High-potential investigation	15,000.00	11,429.08	3,502.26	68.66
Testing structural materials	a 222,733.04	212,166.50	7,636.81	2,929.73
Testing machines	30,000.00	26,314.13	3,304.88	380.99
Investigation fire-resisting properties	25,000.00	21,057.38	3,485.48	457.14
Investigation public-utility standards	b 55,394.84	44,594.04	5,519.56	5,281.24
Investigation railway materials	15,000.00	12,053.25	2,800.15	146.60
Testing miscellaneous materials	30,000.00	24,706.35	4,602.15	691.50
Radio research	20,000.00	18,763.23	1,231.00	5.77
Color standardization	10,000.00	8,143.04	1,800.56	56.40
Investigation clay products	20,000.00	16,329.91	3,391.13	278.96
Determining physical constants	5,000.00	4,540.40	433.38	26.22
Standardizing mechanical appliances	10,000.00	5,315.43	4,620.80	63.77
Investigation of optical glass	c 84,388.75	70,213.74	12,653.68	1,521.33
Standard materials	4,000.00	3,278.02	641.97	80.01
Investigation of textiles, etc	10,000.00	6,407.06	3,129.28	463.66
Sugar technology standards	d 21,350.00	15,731.47	5,512.69	105.84
Gauge standardization	e 433,000.00	367,291.84	64,329.28	1,378.88
Renewal of storage batteries	20,000.00	2,575.09	16,358.25	1,066.66
Military research, 1918–19	f 566,547.68	510,211.49	45,574.00	10,762.19
Investigation of mine scales and cars. 1918–19	15,000.00	10,796.17	4,005.08	198.75
Investigation of public-utility companies, 1918–19	g 53,522.52	38,813.98	14,024.11	684.43
Testing railroad scales, etc	40,000.00	35,220.83	4,102.73	676.44
NATIONAL SECURITY AND DEFENSE.				
Military researches	100,000.00	59,941.04	36,712.06	3,346.90
Robert's coke oven	80,000.00	29,753.46	45,312.99	4,933.55
Thermite investigation	4,300.00	3,454.25	780.16	65.59
Altitude laboratory	60,000.00	59,897.19	....	102.81
Power plant equipment (industrial laboratory)	31,500.00	34.86	31,459.75	5.39
Completing laboratories	235,000.00	169,327.32	65,024.68	648.00
Armament of fortifications, Commerce transfer	h 131,850.00	58,872.71	72,875.93	101.36
Aviation, Navy, Commerce transfer	5,000.00	4,177.14	821.86	1.00
Equipping laboratory. 1919-20	100,000.00	3,026.92	17,882.22	79,090.86
Industrial research, 1919–20	50,000.00	5,195.11	383.13	44,421.76
Total	3,074,446.83	2,285,829.74	566,863.96	221,753.13

a Includes reimbursement of $129 000 from other departments.
b Includes reimbursement of $5 394.84 from other departments.
c Includes reimbursement of $64 388.75 from other departments.
d Includes reimbursement of $1 350 from other departments.
e Includes allotment of $283 000 from War Department.
f Includes reimbursement of $216 547.68 from other departments
g Includes reimbursement of $3 522.52 from other departments.
h Includes reimbursement of $31,850 from other departments.

The following statement shows the condition of the appropriation for the two preceding fiscal years at the close of business June 30, 1919:

Appropriation.	Amount appropriated.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1917.				
Salaries	$311,720.00	$289,777.80	....	$21,942.20
Equipment	50,000.00	49,613.52	$386.48	....
General expenses	28,500.00	28,276.36	223.64	....
Repairs and alterations	5,000.00	4,731.39	34.85	233.76
Grounds	6,000.00	5,935.67	....	64.33
High-potential investigation	15,000.00	14,874.83	4.40	120.77
Refrigeration constants	15,000.00	14,934.19	15.00	50.81
Testing structural materials	100,000.00	99,014.41	259.08	726.51
Testing machines	30,000.00	29,716.27	29.69	254.04
Investigating fire-resisting properties	25,000.00	24,910.75	....	89.25
Public-utility standards	40,000.00	39,704.87	20.04	275.09
Railway materials	15,000.00	14,856.49	92.34	51.17
Testing miscellaneous materials	20,000.00	19,901.12	2.17	96.71
Radio research	a 15,359.71	14,651.73	....	707.98
Color standardization	10,000.00	9,740.45	100.00	159.55
Clay products	10,000.00	9,973.39	....	26.61
Physical constants	5,000.00	4,471.62	57.53	470.85
Standardizing mechanical appliances	10,000.00	9,482.81	343.87	173.29
Testing railroad scales, etc	44,750.00	44,558.89	52.58	138.53
Equipping chemical laboratory, 1916–17	35,000.00	34,790.70	209.30	....
Equipping chemical laboratory, 1917–18	35,000.00	34,697.59	5.26	297.15
Radio laboratory	90,000.00	86,688.97	3,277.00	34.03
Total	916,329.71	885,303.85	5,113.23	25,912.63
FISCAL YEAR 1918.				
Salaries	348,900.00	316,613.53	....	32,286.47
Equipment	55,000.00	53,670.45	1,329.55	....
General expenses	35,000.00	33,563.57	599.43	837.00
Repairs and alterations	5,000.00	4,945.18	46.00	8.82
Grounds	6,000.00	5,801.66	47.66	150.68
High-potential investigation	15,000.00	14,182.62	658.47	158.91
Testing structural materials	b 204,773.83	177,199.80	27,319.21	254.82
Testing machines	30,000.00	29,140.89	440.88	418.23
Investigation of fire-resisting properties	25,000.00	24,849.62	33.19	117.19
Public-utility standards	50,000.00	49,928.19	71.81	....
Investigation of railway materials	15,000.00	14,498.73	212.27	289.00
Testing miscellaneous materials	20,000.00	19,951.28	28.84	19.88
Radio research	10,000.00	9,969.24	....	30.76
Color standardization	10,000.00	9,381.30	532.88	85.82
Investigation of clay products	10,000.00	9,994.53	....	5.47
Physical constants	5,000.00	4,994.31	....	5.69
Standardizing mechanical appliances	10,000.00	9,563.18	9.65	427.17
Investigation of optical glass	10,000.00	9,789.78	135.50	74.72
Testing railroad scales	40,000.00	39,591.44	165.57	242.99
Additional land	25,000.00	....	....	25,000.00
Military research, 1917–18	c 485,818.01	444,415.32	35,800.69	5,602.00
Gauge standardization, 1917–18	d 226,972.47	222,746.62	3,539.40	686.45
Repairs, power plant	12,000.00	11,566.87	177.70	255.43
National security and defense.				
Production of optical glass	e 112,762.00	108,222.22	1,473.92	3,065.86
New building	250,000.00	249,070.44	877.09	52.47
Metallurgical work	100,000.00	97,606.07	2,146.63	247.30
Production of fabrics	35,000.00	24,904.23	10,078.28	17.49
Industrial laboratory	893,500.00	883,223.97	9,796.03	480.00
Robert's coke oven	5,000.00	4,633.45	76.61	289.94
Thermite investigation	700.00	651.60	4.00	44.40
Total	3,051,426.31	2,884,670.09	95,601.26	71,154.96

a Includes reimbursement for $15,359.71.
b Includes reimbursement of $54,773.83 from other departments.
c Includes reimbursement of $235,818.01 from other departments.
d Includes reimbursement of $1,972.47 from other departments.
e Includes reimbursement of $37,762 from other departments.

Summary of Tests.

The Bureau's work includes, among other things, a large amount of testing standards, measuring instruments, and materials. Incident thereto much testing 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 1918–19 the Bureau made 124,668 tests and inspected 5,076,961 incandescent lamps at various factories for other departments of the Government. Of the total tests, 110,468 were for the Government and 14,200 for the public. The testing was distributed as follows, according to the nature of the tests: Length measures, 9,951; mass, 2,022; capacity, 186; optical, 2,161; hydrometry, 3,485; time, 2,278; temperature, 19,164; electrical, 3,570; photometry, 3,510; chemical, 22,664 (physical and mechanical tests); engineering material, 1,593; structural material, 44,738; paper and textile, 8,162; metallurgical, 539; aeronautical instruments, 645. The estimated fees amount to $677,873.64, of which $21,169.16 was collected on account of tests for the public. The fees noted for Government tests were included merely for comparison purposes, as no fees are charged for tests performed for the National or State Governments.

NUMBER AND VALUE OF TESTS COMPLETED, FISCAL YEAR ENDING JUNE 30, 1919.

AT WASHINGTON.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length	9,482	$14,477.45	469	$598.10	9,951	$15,075.55
Mass	1,060	26,785.10	962	491.30	2,022	27,276.40
Capacity	136	1,203.21	50	112.25	186	1,315.46
Optical	1,863	4,171.50	298	1,372.46	2,161	5,543.96
Hydrometry	1,360	1,047.35	2,125	1,080.75	3,485	2,128.10
Time	2,194	867.25	84	309.50	2,278	1,176.75
Temperature	15,892	3,379.81	3,272	3,568.95	19,164	6,948.76
Electrical	1,878	7,738.25	1,692	5,499.75	3,570	13,238.00
Photometry [a]	3,421	12,989.00	89	307.75	3,510	13,296.75
Chemical [b]	19,264	198,461.01	3,400	6,549.35	22,664	205,010.36
Physical and mechanical—						
Engineering material	1,538	6,492.00	55	234.00	1,593	6,726.00
Structural material	43,166	338,496.05	1,572	507.00	44,738	339,003.05
Pittsburgh laboratory	3,572	11,606.50	48	165.00	3,620	11,771.50
Paper and textile	8,096	30,253.00	66	262.25	8,162	30,515.25
Metallurgical	522	1,616.00	17	196.00	539	1,812.00
Aeronautical instruments	596	8,727.50	49	79.75	645	8,807.25
Total	114,040	668,310.98	14,248	21,334.16	128,288	689,645.14

AT PITTSBURGH.

Cement	2,804	$7,924.00			2,804	$7,924.00
Clay products	61	673.00			61	673.00
Miscellaneous	122	936.00	47	$155.00	169	1,091.00
Chemical	585	2,073.50	1	10.00	586	2,083.50

[a] In addition the Bureau inspected 5,076,961 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $12,692.40.

[b] Of these tests 8,091, amounting to $121,365. were chemical tests made on structural material.

PERSONNEL.

(Organization charts of divisions; staff status, individual records of all employees, including military employees; appointments and 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 the military service.)

The work in the personnel section covers a wide range of functions, all pertinent to personnel work, but involving a large volume of clerical detail. All of such routine has been carefully standardized, and a system of process charts was adopted. Each function shows the steps required and the action points. These serve as a guide in standardizing procedure and to instruct new clerks.

Present Personnel.

During the year the Bureau staff comprised 341 statutory employees and about 809 engaged in research and investigations specially authorized by Congress. The statutory positions included 201 scientific positions, 52 office assistants, 55 engaged in the operation of the plant, and 33 in the construction. In addition to the above there were 300 employees detailed from other Government departments and organizations during the year for work in the Bureau. The Bureau more than doubled its force during the war.

Effect of War and Armistice on Personnel.

The personnel at present consists of over 1,000 regular appointed employees, as compared with approximately 500 prior to the war. The highest number of employees at any one time during the year was approximately 1,450, of which 300 included detailed employees from the Army, Navy, or other Government establishments. On June 30, 1919, there were 1,140 employees, of which 60 were detailed employees. The above figures show that the force has been reduced by approximately 310 employees since the armistice was signed. These included 240 detailed employees and 70 regular employees.

Personnel Changes.

There were 4,300 personnel changes during the year. These included 1,505 separations from the Bureau, of which 378 were resignations, 774 promotions, and 1,909 appointments. The high labor turnover will give some idea as to the large amount of work required in keeping positions filled. How serious is the unusually heavy drain, due to the demand for trained employees, is shown by the fact that 1,505 out of a total force of 1,909 regular appointed employees, or over 78 per cent, left the service during the past year. A detailed statement of the personnel changes is given in the following table:

PERSONAL CHANGES, 1918–19.

Nature of position.	Appointments.	Separations.
Competitive	554	372
Excepted	14	1
Unclassified	27	5
Total permanent	595	378
Temporary	1,314	1,127

Summary.

Appointments	1,909
Separations	1,505
Promotions	774
Reductions	23
Other changes	89
Total personnel changes	4,300

Personnel Records.

The personnel charts were revised during the year and placed in book form, with a new type of visible index. This provides a neat graphic record of the staff status instantly accessible and visible and facilitates the entries of personnel changes. A list of all employees by grades and seniority on all funds was compiled during the year. This record is on a visible index file and shows at a glance all employees in each grade by seniority. Such data are so often called for that considerable time will be saved in preparing lists. An efficiency record is kept of all junior employees.

Annual and Sick Leave.

The following table shows the total and average amount of annual and sick leave taken by the employees of the Bureau during the calendar year 1918:

Leave.	Days.	Average.
Annual	6,362	15.0
Sick	2,296	5.4
Total, 1918	8,658	20.4
Average in 1917		24.8

Eligibles.

A satisfactory arrangement was effected to secure prompt certification of eligibles in important cases. This saves at least 10 days in making appointments. Owing to the variety of experts required and the heavy demand for labor, the civil-service registers proved inadequate. It was necessary to seek temporary assistants in nearly 75 per cent of the cases, nearly all of whom subsequently qualified by examination and were given permanent appointments.

Employees in Military Service.

Approximately 90 employees left the Bureau to enter the organized military service during the war, 2 of these having been killed in action, 1 dying of disease, and 1 dying by accident. Employees who entered the military service and who have applied for reinstatement are being restored to the Bureau rolls in their old positions. In no case has the salary offered been less than that which the employee was receiving when he left the service. Many of the Bureau's experts were necessarily retained for scientific research in connection with military problems.

Additional Work.

The method prescribed by law for recommending employees for the bonus entails much extra work on the personnel section. Individual recommendation is required in each case where the employee has entered the service since June 30, 1918, or where employees have been promoted in excess of $200 since that date. It is also necessary to keep records of the bonus for immediate reference, it being necessary to verify each change in an employee's status. Detailed data is also furnished to the Commission on Reclassification of Salaries as to each personnel change, and duties of old and new positions.

PUBLICATIONS.

(Editorial work, routing of manuscripts and proof documents; archives; handling requests for publications, preparing franks; publication stock distribution; abstracts of publications.)

Publications Issued During Year.

The publication work of the Bureau was reduced to a minimum during the war, so that all possible service might be rendered to the military departments directly in experimental and investigational work. However, during the fiscal year the Bureau issued 53 publications, 36 of which were new and 15 revised editions. Forty publications were reprinted without revision. The new publications comprised 12 scientific papers, 15 technologic papers, 6 circulars, and 3 miscellaneous publications, as listed below:

Scientific Papers.

Wave Lengths in the Red and Infra-red Spectra of Iron, Cobalt, and Nickel Arcs.

Spectroradiometric Investigation of the Transmission of Various Substances.

Electrical Oscillations in Antennas and Inductance Coils.

Measurements on the Index of Refraction of Air for Wave Lengths from 2218-A to 9000-A.

Variance of Measuring Instruments and Its Relation to Accuracy and Sensitivity.

Measurements of Wave Lengths in the Spectrum of Neon.

The Decrease in Ultra-Violet and Total Radiation with Usage of Quartz-Mercury Vapor Lamps.

A Relation Connecting the Derivatives of Physical Quantities.

Preliminary Determination of the Thermal Expansion of Molybdenum.

Optical Conditions Accompanying the Striæ Which Appear as Imperfections in Optical Glass.

A Simplification of the Inverse-Rate Method for Thermal Analysis.

Combustible-Gas Detectors.

Technologic Papers.

Determination of Permeability of Balloon Fabrics.

A Portable Cubic-Foot Standard for Gas.

New Baumé Scale for Sugar Solutions.

Silica Refractories—Factors Affecting their Quality and Methods of Testing the Raw Materials and Finished Ware.

Toluol Recovery.

A Critical Study of the Ledebur Method for Determining Oxygen in Iron and Steel.

The Ultra-violet and Visible Transmission of Eye-protective Glasses.

Tests of Hollow Building Tiles.

Strength and Other Properties of Wire Rope.

Tests of Eighteen Concrete Columns Reinforced with Cast Iron.

Physical and Chemical Tests of the Commercial Marbles of the United States.

Constitution of Silica Brick and Changes Involved Through Repeated Burnings at High Temperatures.

Viscosity of Gasoline.

A Study of the Goutal Method for Determining Carbon Monoxide and Dioxide in Steel.

The Effect of Solar Radiation upon Balloons.

Circulars.

Publications of the Bureau of Standards.
Aluminum and Its Light Alloys.
The Table of Unit Displacement of Commodities.
Solders for Aluminum.
Electrical Characteristics and Testing of Dry Cells.
Recommended Specification for Linseed Oil—Raw, Refined, and Boiled.

Miscellaneous.

Proceedings of the Second Annual Textile Conference Held at the Bureau of Standards (1917).
Metric Manual for Soldiers.
Annual Report of the Director for Fiscal Year Ended June 30, 1918.

Distribution.

As provided by law documents are mainly distributed by the Superintendent of Documents. A proper selection of suitable publications to be sent in response to many of the requests for technical data can be made only in close contact with the technical sections of the Bureau. The franks, therefore, are prepared at the Bureau in the publication section.

List of Publications.

During the year the Bureau completed and published a full list of publications issued by the Bureau since its establishment. The catalogue is descriptive and gives for each title a technical abstract of the publication, and a comprehensive index. The Bureau will issue a quarterly supplement to include new publications published during the quarter. This list of publications has already proved of great value in guiding the economical and efficient distribution of Bureau publications. The abstract gives so clearly the nature of the subject matter that an expert can promptly decide whether the publication meets his need. The abstracts form an excellent summary of the entire published work.

PROPERTY AND STORES.

(Property inspection; quantity and quality checking; accession, recording; accountability, charge and release; condemnation and disposal; stores, stock distribution, and renewals.)

Equipment.

During the year 50,000 pieces of equipment were received, serially numbered, and taken up on the inventory records. New engraving and stenciling machines were procured to facilitate the placing of Bureau accession numbers on all pieces of equipment.

Perpetual Inventory Records.

The improved system of perpetual inventory records is now fully established. All necessary record entries are made at one writing in place of the three separate writings formerly required. This greatly facilitates prompt local and central handling of inventory and property transfers.

Technical Supplies.

During the year technical supplies valued at $65,000 were issued to the various technical divisions and offices. The systematic arrangement and segregation of technical supplies in the storeroom enable the attendants to give quick service, each class of stock having a specific and indexed location. The new card system shows at a glance all stock on hand, amounts issued, and organization unit drawing the same. This permits the complete accounting for all supplies issued and charging of same to proper units. The system works well, and the main storeroom is now supported wholly by reimbursement from allotments to the various divisions.

Additional Space Needed.

Additional space is seriously needed to permit the stock to be kept on one floor, systematically arranged on shelves according to classes of material. The main stock supply is now in the attic. Suitable quarters would reduce by two-thirds the labor in handling supplies, and the attendants could more promptly and efficiently serve the technical needs.

MAIL.

(Handling of incoming and outgoing correspondence of all kinds; the accession, distribution, and filing of such papers.)

Filing System.

Marked progress was made during the year in perfecting the central filing system. An accurate check is now available for the location of each letter. Two sets of reference slips are filed, one according to organization unit of reference and one according to date, the file for incoming and outgoing letters being kept separate. This has saved appreciably in time and labor, and promoted the efficient handling of correspondence.

New Equipment.

A new motor-driven letter opener saves the time of one employee previously needed for the work. A new device designed and constructed at the Bureau is used to photograph all important incoming mail, using for the purpose a motion-picture film. The photographic reference record of incoming letters, by means of a suitable projector, is used to throw the image of the letter on the screen. The original letters, as soon as photographed, are at once available for distribution to the divisions of the Bureau. The saving of one to two hours' delay enables the mail section to deliver the morning mail to the laboratories by 10 o' clock.

Subject Filing.

The Bureau correspondence is filed by subject. In each unit subject, however, a series of monthly folders facilitates the transfer of back correspondence. This simple device greatly simplifies the clearing of the current files and transfer to the permanent cases.

Filing Equipment.

The new equipment obtained for properly handling the large volume of correspondence has included a sorting cabinet, small-letter sorters, filing units, transfer cases, and visible guides. Floor space urgently needed for systematic storage of back correspondence and records is now available, since the photographic shop is transferred to the industrial laboratory.

Personnel.

The mailroom staff has shown cooperation to a marked degree in excelling previous performance in the proper handling of the

Bureau's correspondence. The arrearage of work occasioned by the loss of experienced clerks due to the war has been gradually overcome, and with new equipment already ordered the work can speedily be brought up to date.

LIBRARY.

(Maintenance of scientific and technical library; bibliography; selection of new reference books; preparing book lists for purchases; accessioning new books; loans and accountability records; assistance to technical staff; and binding of books and periodicals.)

Accessioned Volumes.

At the close of the fiscal year the technical library of the Bureau had 17,742 accessioned volumes. Except for a few law books, these are all of scientific and technical character, chiefly in the subjects of physics, chemistry, engineering, and special technology. During the fiscal year 346 new volumes were accessioned.

Technical Journals.

The Bureau receives currently 442 scientific and technical periodicals. During the year steps were taken toward completing some of the more important sets which are in great demand at the Bureau. About one-half of the periodicals are received by exchange with the Bureau's publications. The following is an interesting analysis of the technical journals currently received, including a statement of the total number of separate parts:

	Subscription.	Exchange.	Total journals.	Total parts.
American	84	115	199	3,889
British and others in English	49	55	104	1,645
French and others in French	17	21	38	584
German	69	....	69	1,640
Others	3	29	32	284
Total	222	220	442	8,04

Circulation.

Apart from the consultation of books in the library itself and the desk copies of important texts permanently assigned to the laboratories, there was a monthly average circulation of 500 books and journals. Through the cooperative arrangement with the various libraries in Washington, more than 500 loans were made to the Bureau. In return, the Bureau makes loans to experts in other institutions and tenders the Bureau's facilities and library for consultation and reference.

Additional Space.

In common with every other section of the office, additional space is urgently needed. A new periodical rack is required and additional stacks. The Bureau's library is increasing at a rate to demand approximately 50 additional shelves per year. Furthermore, the question of consolidating the overflow library now located in the attic and transferring it to the main library should receive early attention. This can be done when additional space and stacks are available.

DISPATCH.

(Transportation and communication of all kinds, comprising telephone and telegraph service, express, freight, and mail shipments, drayage, motor-cycle, and other messenger service in and out of the Bureau.)

Shipping.

The consignments handled by the dispatch section of the Bureau during the past year far exceeded the business of any previous year. The system for recording the same has been in successful and satisfactory operation during the year. In view of the variety and the delicate or dangerous nature of the many instruments and materials shipped, the results are gratifying. However, with the consolidation of the Pittsburgh laboratory and the desirability of improving the promptness of the service, especially during peak periods, at least one experienced packer and two laborers should be added to the shipping-room staff.

Quarters.

The present temporary quarters suffice for the present. Permanent provision should be made—probably in another building—for a well-designed shipping room, with loading platform and modern facilities for good traffic management.

PURCHASE.

(Trade catalogues and dealers' lists; requisition inspection; preparation of bids, requests, advertising, and orders; order follow up; purchase and transportation checking.)

Requisitions and Orders.

During the year 8,800 requisitions were placed for supplies and equipment necessitating special orders. A shortening of the routine now permits all orders to be mailed the same day as written, saving a full day's time in each case. The purchase section has placed travel-authorization requests on the same basis as orders, and is handling them efficiently.

Records.

An excellent system of records is in successful operation, and needed information is obtainable promptly. The follow up established during the year proved effective in expediting the checking of material received and payment of vouchers. A special clerk designated as "voucher runner" sees to it that all accounts are handled promptly, or adequate reason is given.

Bids.

The last appropriation act requiring that bids be solicited of all Government departments before purchasing from outside contractors greatly increased the work of securing material and involves some delay in securing needed equipment and supplies.

Space and Assistance.

The concentration of purchase work in the purchase section has entailed much extra work for which additional assistance should be provided to carry it efficiently. Larger quarters will be needed or the efficiency of this service will be impaired.

Catalogue Library.

The Purchase Section maintains an excellent catalogue library arranged alphabetically, by firms, and indexed by classes of articles, including especially scientific and technical equipment and supplies. In addition a record is kept of the location of all catalogues assigned or loaned to the staff.

COPYING.

(Editing rough drafts of letters, reports, and manuscripts; stenography; typewriting; and mimeography.)

The purpose of the copying section can not be efficiently served until an adequate force of typists is available to take over all the principal dictation and general typewriting of the office section. If this proves feasible, the consolidation should be extended to include most of the work of the scientific and technical sections.

The members of the copying section assisted in preparing the details of office practice and procedure charts, including organization charts of routine, staff assignment, and functions in connection with the general office-organization plan. The plan is novel and comprehensive. The details are described in another part of this report. Other work of the section included the loaning of temporary assistance in case of illness or absence on leave, the handling of peak loads of work in various parts of the Bureau, mimeograph work, and the taking of miscellaneous dictation.

The plan for the development of a copying section includes the ultimate provision for a sufficiently large room where all clerks engaged in copying work could work systematically together, so that the assignment and systematic record of work could be facilitated.

INFORMATION.

(Reference of technical correspondence; 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 and to some extent for civilian agencies; requesting, receiving, distributing, and filing of scientific and technical information of a military bearing.)

Progress-of-Work Records.

The initiation and progress of tests, investigations, and researches is charted for military and related work. This now includes the more important nonmilitary work. This forms an available and full list of the more important technical activities of the Bureau. During the year 4,209 separate military entries were carried on the progress-of-work chart, averaging 351 per month, and, in addition, 220 important industrial investigations were charted. The entries include dates of incoming letter, receipt at the Bureau, receipt of the materials or specimens to be tested, and of preparation of final report and its mailing, and also the subjects of incoming and outgoing correspondence concerning the case. A systematic follow up and record thereof is provided.

The novel form of chart and notation used has attracted interest outside and is being published by a firm publishing forms and digests of data for technical work.

Distribution of Technical Information.

The Bureau receives many technical and scientific data, to some extent confidential in character. The sources include the Research Information Service of the National Research Council, the Air Service Information Group, the reference library of the Ordnance

Department of the Army, the Bureau of Construction and Repair of the Navy Department, and the National Advisory Committee for Aeronautics. Such data are referred to the proper technical division to be utilized as promptly and fully as possible.

The information section also obtains upon request of any authorized member of the staff documents of this character available at any of the usual sources of such information. Six hundred and twenty-one separate documents of this character have been secured on such requests during the past nine months.

Technical News Bulletin.

The Bureau has dispatched at frequent intervals since December, 1917, to the military and naval technical and executive authorities and other cooperating services, a confidential bulletin of brief current news of technical and scientific progress in the Bureau's laboratories. The diffusion of up-to-date data made it possible for officers of other services concerned to arrange for needed cooperative work and for early application of the results when exigent work required.

Recently the confidential nature of the bulletin has been largely eliminated, and it is now issued as the Technical News Bulletin of the Bureau of Standards, a few confidential matters of military importance being reserved for a confidential supplement sent only to a restricted mailing list. During the past fiscal year the confidential or news bulletin has included 135 single-spaced mimeographed pages, under a total of 426 separate subject headings. The many inquiries for information about work in progress based upon this bulletin shows that it has performed useful service in making technical information available for early use.

Miscellaneous Information Service.

The information section handles many inquiries by telephone and otherwise for information regarding the Bureau's work and puts the inquirer in touch with the proper staff expert, a matter of importance now that the organization is so large and comprises so many and varied activities. Compilations of information required for various purposes are also undertaken—as, for example, at the request of the War Department a history of the Bureau's technical participation in the work of aircraft production—and for general use and information an analysis of the memberships of experts of the Bureau staff in committees of the various technical and scientific societies with which the Bureau cooperates.

IV. ENGINEERING AND CONSTRUCTION.

1. POWER PLANT, BUILDINGS AND GROUNDS, AND TRANSPORTATION.

[Power-plant operation, automobile and truck service, electrical and plumbing installation and repair, care of buildings and grounds, engineering supplies storeroom.]

Operation and Maintenance of Mechanical Plant.

The operation and maintenance of the power plant is a very important part of the work of the engineering division, in that the entire Bureau is dependent thereon for the various laboratory facilities. The power plant comprises the heating, generating, and refrigeration equipment, the compressed air, vacuum, and high-pressure water services, and the storage-battery equipment, both stationary and portable. During the past year a number of additions were made to the several types of equipment of the plant in those departments which were critically in need of additional facilities. Two 200-horsepower boilers were put in operation during the past winter and made possible adequate heating of the Bureau. At present the intallation of two 350-horsepower boilers in the basement of the kiln building for heating the industrial and kiln buildings is nearing completion. Additions to the electrical equipment during the year include a 300-kilowatt synchronous converter and 200 kilovolt-amperes in transformers. The converter, while not exactly satisfactory from an operating standpoint, is, nevertheless, a great help in insuring uninterrupted direct-current service. The transformers were added in order to accommodate several large electric furnaces installed for the metallurgical and heat and thermometry divisions.

The stationary storage batteries were renewed during the year and put in excellent condition, a special appropriation having been provided for the purpose. A number of new portable storage batteries were also added to the plant equipment. The rapid expansion of the Bureau in all its branches, due to its war-time activities, has placed a severe strain on the power plant, and, while the additions above mentioned have provided means for temporarily supplying the various laboratory facilities, the present arrangement of the power-plant equipment is far from satisfactory both from an operating standpoint and on account of the sizes of the units and variety of equipment, and must, therefore, be considered as only of a temporary nature. For instance, the entire floor space of the present engine room has been used for machinery and switchboards, and the synchronous converter necessarily placed in the northwest building, some distance away; the boilers in the kiln building will require separate operating crews, both of these cases being an indication of how the operation of the plant has become decentralized. It was with difficulty that the operation of the plant was managed during the past winter, and it was only made possible with several labor-saving devices which were put into effect in the method of coal and ash handling. The construction of a separate heating and generating plant, including all the mechanical equipment adequate for the present and future requirements of the Bureau, should be undertaken at once not only as essential to better efficiency, but also as a necessity against serious interruptions of service, which are, indeed, quite probable with the present plant. The plant has expanded to a point where further temporary expansion is almost impossible, and its capacity is frequently taxed almost to the limit.

Transportation.

The operation and maintenance of the transportation equipment of the Bureau is cared for by this section of the engineering division. The equipment consists of 2 touring cars, 1 ambulance, 1 mail truck, and freight-handling trucks of the following capacities: One $2\frac{1}{2}$-ton, two $\frac{3}{4}$-ton, two 500-pound. Owing to the very large increase in the work of the Bureau, due to its war activities, the importance of maintaining adequate truck service to handle the freight, express, etc., with dispatch is readily apparent. The maximum service possible was obtained from the various machines, and consequently hard usage has rendered some of the trucks unfit for much more useful service. Steps are being taken to obtain additional trucks of larger capacity, and when put into operation they will greatly relieve the present conditions. Additional space is urgently needed for the garage besides the temporary building constructed during the year to house four machines not used for freight handling. Methods of better adapting the present equipment by changes in construction, etc., are being considered and will probably be carried out during the coming year.

Construction and Repair.

Electrical.—The installation of all electrical wiring, switchboards, and equipment for laboratory purposes and for maintenance of the power plant is performed by this section. Owing to the character of the research work of the Bureau the electrical work is in many cases unusually complicated, requiring very skilled mechanics. Besides the installation of the equipment, this section also repairs and extends this equipment as required. During the past year the installation of equipment in the northwest and radio buildings was practically completed. There were included in these installations several electric furnaces of large capacity, wiring of machine tools, battery installations, and many extensive additions made to the electrical work throughout the entire Bureau.

Plumbing.—The installation of all pipe work required for various laboratory facilities, including steam, gas, air, vacuum, water, and refrigeration, is done by the plumbing section. Here, again, owing to the nature of the equipment, which is installed for various laboratory purposes, well-trained mechanics are necessary for the pipe work to be done. The work during the past year, besides including completion of the equipment piping in the northwest and radio buildings, also covered a very large number of extensions of piping throughout the remainder of the Bureau and a very large amount of repair and maintenance work of the plant equipment. In both the electrical and plumbing sections additional help is urgently needed, and working space with adequate tools and facilities is a pressing necessity. It is possible that, in the very near future, sufficient room for a workshop for the plumbing and electrical sections will be obtainable, and such an addition should greatly increase the efficiency of these sections and improve the character of the work performed.

Minor Construction.—Under this section are included various small jobs of construction, such as the building of temporary structures, construction and repair of concrete roads, and repairs and alterations to existing buildings. The personnel of this section is at present entirely inadequate owing to the large number of small jobs always on hand. During the past year a temporary building was constructed for housing four automobiles, concrete roads were repaired, and about 200 feet of new roadway built of cinder concrete. Paths of cinder concrete blocks aggregating 600 feet in length were also constructed. Numerous extensions were made to the drainage system of the Bureau grounds, and the construction of retaining walls was begun. A number of repairs and alterations were also made to buildings, including partitions, skylights, painting, etc.

Buildings and Grounds.

Janitors and Laborers.—The work of this section is of more or less routine nature and comprises the cleaning of the many offices and laboratories of the Bureau and the maintaining of sanitary conditions throughout. Owing to the shifting of the laboratories, due to expansion, there was a considerable amount of moving of equipment, and in all cases where such moving was handled through this section during the past year the work was done most economically. During the past year the dynamometer and industrial buildings were practically completed, and the northwest and radio buildings, completed during the previous year, were fully occupied by laboratories. There should be a material increase in the personnel of the janitors and laborers to care efficiently for the buildings now completed.

Guards.—During the period of the war all of the Bureau buildings were kept under guard, and men were stationed at the entrance doors of the buildings for this purpose, as well as at the entrance to the Bureau grounds. Rigid inspection of all visitors was exercised, and only such persons as could show satisfactory reasons were permitted to enter the Bureau. Early in the year 1919 the guards were removed from the entrance doors of the buildings, but the inspection and direction of visitors is continued at the entrance of the Bureau grounds.

Officer of the Day.—This office was provided for the purpose of having at the Bureau at all hours some one authorized to represent the Director in all circumstances requiring the decision of a responsible officer, when the Director was not at the Bureau. The office was filled by members of the Bureau staff, each of whom was on duty for 24 hours, during which time he did not leave the Bureau. In order that this office should not work a hardship on any one person, no one was required to serve as officer of the day more than one day per month. The numerous occasions upon which this office proved to be of special advantage are conclusive evidence that the position should be permanently authorized and adequate compensation given the incumbent, inasmuch as the members of the Bureau staff have so far served as officer of the day voluntarily and without extra compensation.

Watchmen.—The duties of the watchmen are to make inspections of the buildings to prevent fire, theft, damage by weather, etc., to the

Bureau property. The additional buildings recently completed have added considerably to the extent of the work required by the watchmen, and, while a small addition has been made to the number of watchmen employed, the personnel of this section is still inadequate and should be materially increased for efficient inspection of all the laboratories.

Grounds.—The care and improvement of the grounds of the Bureau is included in the work of this section. Owing to the extensive building operations during the past year, certain portions of the Bureau grounds could not be taken care of as well as they should have been. It was also found quite difficult during the past year to obtain labor at such times as it could be used to the best advantage in maintaining the proper care of the grounds.

2. PHOTOGRAPHIC LABORATORY.

[Investigation of photographic apparatus; testing of photographic materials and apparatus; standardization of testing apparatus and conditions; general photography.]

Sensitometer.

A sensitometer has been designed and constructed for testing the light-sensitive characteristics of plates and films. This apparatus consists of three parts: (1) The sensitometer for making accurately known exposures, (2) the thermostated developing bath, and (3) the photometer for measuring the test specimens. A circular describing this apparatus and method of testing was prepared and distributed to those interested in this work.

More than 100 tests of stained and bathed plates were made with this apparatus for the optical section. This work formed a part of a military problem in connection with the taking of photographs from airplanes, and will be found to be treated more fully under "Aerial Photography" in the report of the optical division.

Developer Testing.

Samples of methol substitutes and other developers were tested for several Government departments.

Photographing the Mail.

An experimental camera for photographing the mail of the Bureau has been constructed and is found to save considerable time in briefing and recording the incoming mail. This mail formerly was held in the file room until the records and brief were made, and was then delivered to the various sections of the Bureau. By the photographic method the mail is photographed on motion-picture film as soon as received and immediately delivered to the laboratories. The photographing requires from 10 to 20 minutes for the entire mail. The film negatives are projected to original size by means of a small projection lantern and the brief and file cards made. The cost is very moderate; 16 letters are copied on each foot of film.

General Photography.

During the past fiscal year more than 2,200 miscellaneous photographic requisitions were completed. These requisitions called for photographic work of all descriptions. Much of this was in connection with the Bureau's military problems. In addition to this, the entire personnel of this Bureau (approximately 1,500) were photographed for pass and identification purposes.

V. GENERAL RECOMMENDATIONS.

Salaries.

So much has been said in former reports, in the submission of estimates and the public press as to the inadequacy of salaries of scientific and technical experts in the Government service that it seems almost unnecessary to call attention at this time to a condition so well known.

The disparity existing between the salaries of these experts in the Government service and elsewhere is so great that the scientific work of the Government is rapidly being affected accordingly. It is true that the conditions existing in connection with the war have necessitated many changes in the scientific personnel of the Bureau. Nevertheless the number of changes during the past year amounts practically to 100 per cent. No work can be efficient upon that basis. Such changes are disastrous to scientific or technical work.

In submitting the estimates for the Bureau of Standards for the coming year it has been assumed that the Joint Committee on Reclassification of Salaries will thoroughly investigate this question and make recommendations accordingly. All positions, whether old or new, submitted in the estimates for 1920–21 are with the expectation that they will be adjusted by Congress to a new and adequate scale.

Power Plant.

The power plant of the Bureau of Standards is entirely inadequate. It now consists of the original plant constructed for two buildings and two temporary installations. These installations should be brought together under one roof in the form of a small but model power plant capable of heating the various buildings now existing, with provisions for its extension in the future. It should also provide the various electrical currents for power and experimental purposes, as well as other utilities required at the Bureau. The need for this power plant has existed for the past three or four years, but it was thought unwise to begin new construction during the war. A thorough report has been made on the situation by one of the most competent firms of consulting engineers in the country. It is estimated that such a power plant will cost in the neighborhood of $500,000. An estimate for preparing the plans and beginning the construction of the building for such a power plant will be submitted.

Remodeling of Building for Mechanical Plant.

The building in which are housed the instrument shops and much other construction work was the first erected at the Bureau, and has become entirely inadequate for the purpose designed. A remodeling of the roof of this building will make available an entire story. Provisions for this alteration have been requested in the former estimates and will be resubmitted for the years 1920–21.

Additional Land.

I would again call attention to the urgent necessity for acquiring the plot of ground between the Bureau's site and Van Ness Street on the north and that between the Bureau's grounds and Tilden Street on the south. Estimates have been submitted previously, and an appropriation was made two years ago. This, however, proved to be inadequate. A careful study has been made of the situation and an estimate will be resubmitted. It is to be regretted that, through misunderstandings and the great difficulty which always attends the purchase of real estate, these strips have not been secured heretofore, as it was evidently the intention of Congress when the appropriation was made that they should be acquired.

Care of Buildings and Grounds.

It has been practically impossible, as well as inadvisable, to expend much money or labor upon the improvement of the grounds during the war period. Nevertheless, the time has come when a sufficient sum should be provided for the development of a simple but appropriate plan for the grounds of the Bureau of Standards and the putting of the same into effect. The appropriations for this purpose in the past have been such as to cover only a small amount of the most urgent improvements in the way of roads, walks, pipes, wires, etc. An estimate will be submitted for the purpose. It is realized that this cannot be accomplished in a single year, but the most necessary improvements should be provided for at once.

Test-Car Depot.

Estimates will be submitted for a small building in which to house and care for the Bureau's test cars and master track scale. This building should be situated at some central place. This important service can be made more efficient by providing a small depot centrally located. Every effort has been made to handle this from Washington, but experience has shown that a small substation centrally located is necessary.

Respectfully,

S. W. STRATTON, *Director.*

To Hon. WILLIAM C. REDFIELD,
Secretary of Commerce.

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