ANNUAL REPORT

OF THE

DIRECTOR
BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1916

WASHINGTON
GOVERNMENT PRINTING OFFICE
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REPORT

OF THE

DIRECTOR, BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 1, 1916.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1916.

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 the broad and modern sense.

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

1. STANDARDS OF MEASUREMENT.

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

The construction of a set of standard weights from a single unit is also an illustration; a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. When the standard of length or weight has been found with as many desirable qualities as possible, and before the working standards of the subdivisions or multiples can be prepared, the question as to the method of comparison arises, which again involves the solution of difficult scientific problems in connec-

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

tion 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 commercial transaction.

2. PHYSICAL CONSTANTS.

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

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

3. STANDARDS OF QUALITY.

A standard of quality for a given material may sometimes take the form of a sample of that material with which other materials of the same kind can be compared, but this is generally a makeshift of the poorest sort. It is only resorted to in the absence of definite and reliable specifications in terms of measurable properties; that is to say, a standard of quality of a material usually takes the form of a specification or definition of its properties, involving, of course, the measurement of those properties by means of the usual standards of measurement. A certain kind of steel, a cement, a paint, an oil, or a paper or cloth is found by use to be good or poor. The questions

then arise, Why is it good or poor; What are the physical or chemical properties or the particular combination of elements which make it of good or poor quality; How are its properties to be measured or its constituents determined? These are questions for the laboratory to answer and involve physical and chemical investigations of the most difficult sort.

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

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

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

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

4. STANDARDS OF PERFORMANCE.

The value of an instrument, device, or machine almost always depends upon the efficiency of its performance. In such cases it is necessary to state the performance desired or guaranteed in terms

which are correct and susceptible of measurement. As in the case of standards of quality, the standard involved is more often in the form of a specification, but specifications are useless unless based upon correct scientific and mechanical principles and supplemented with a statement of the method to be used in ascertaining whether or not the specifications or guaranties have been complied with.

The performance of an engine or boiler, a pump, an electrical generator or motor, a weighing device, or a telescope can usually be measured, but the quantities to be measured and the method used must be specified correctly and understood by all the parties concerned in the construction, purchase, or use of such apparatus. To do this properly involves the use of standards of measurement, 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.

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

5. STANDARDS OF PRACTICE.

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

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

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

The Bureau compares with its own standards of measurement the standards or measuring instruments of States, cities, scientific laboratories, educational institutions, manufacturers, Government bureaus, or the public, for which a nominal fee is charged, except in the case of the National and State Government institutions. It gives advice concerning these standards or their use, whether it be in connection with the enactment of laws, regulations, or ordinances concerning the weights and measures of everyday trade or in connection with

precision standards used in scientific work and the industries. It gives advice upon request to State and city officials, public-service commissions, and public-utility corporations regarding the standards of measurement, or quality, or performance involved in legislation or regulation pertaining to the public utilities. Many questions of disagreement between the public and utility companies as to these matters are referred to the Bureau for advice or adjustment, often avoiding unfair or inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. As far as possible such information is given in the form of publications upon definite subjects.

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

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

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

scientific and technical standards other than weights and measures; and the Prussian Government maintains the Materialprüfungsamt, a large institution devoted to the investigating and testing of structural, engineering, and other materials.

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

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

The bureaus of the Government engaged in scientific and technical work are necessarily dependent upon standards of measurement of every variety. In addition, many of them are engaged in the design, construction, and specification of a great variety of special apparatus, in which the principles of mechanics, heat, optics, electricity, and chemistry are involved and are vital to their efficiency and successful operation. In such matters the Bureau has been consulted most freely by the War and Navy Departments, the Post Office Department, the Department of Agriculture, the Public Health Service, and others.

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

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

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

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

8. ORGANIZATION.

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

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

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

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

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

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

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

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

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

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

9. LOCATION.

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

II. SCIENTIFIC AND TECHNICAL DIVISIONS.

1. WEIGHTS AND MEASURES.

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

Weights and Balances.

Plans have been nearly completed for shortening the time required for testing the large number of analytical weights received at the Bureau, without, at the same time, lessening the thoroughness of the test. This is made possible by the use of a balance recently purchased and slightly modified at the Bureau, the construction of which permits the addition of small weights without opening the case and the use of counterpoise weights in such a way that their values need not be recorded. A comprehensive test of the constancy and reliability of this balance has been commenced.

A slightly larger number of weights were tested during the year just closed than the previous one, the total number being 3,501, exclusive of 967 weights belonging to the Bureau. Of the former number, 1,620 were for technical laboratories, educational institutions, manufacturers, dealers, etc., and 1,881 were for the various branches of the Federal Government, nine States, and the island of Porto Rico.

A set of coin weights was constructed during the year, which will be used principally for verifying the weights used by the assay commission in its annual test of coins at the mint at Philadelphia and also for verifying coin weights submitted to the Bureau by the mint or by the States. On account of the odd values of coin weights, the set recently constructed will greatly facilitate the verification of weights of this class submitted to the Bureau.

An investigation with special reference to the proper placing and alignment of the knife edges of high-grade precision balances, and also as to the straightness of their knife edges and bearings, has been continued during the year; but on account of the large amount of routine testing to be done, the investigation could not be carried to the extent that the importance of the work deserves. The object of this research is to enable the Bureau to establish standard specifications, tolerances, and methods of testing high-grade precision balances. A circular on this subject is greatly needed by both manufacturers and users of this class of weighing instruments.

Length Measures.

About 500 length standards were tested during the year, of which 277 were tapes of either steel, invar, or linen; the remainder included a number of yard and meter standards, several sets of gauges of various kinds, calipers, precision screws, level rods, and sieves. The increase in the amount of this work has largely interfered with the checking up of our standards.

Testing of Gauges, Taps, Dies, Micrometers, Etc.

A matter of great importance to the national welfare, in case the country should be called upon to defend itself, is the measurement of gauges, taps, dies, micrometers, etc., in order to determine whether they are within the tolerances which must necessarily be specified if the material is to be of any value. The work in this field which the Bureau already receives is sufficient to keep two men occupied without doing any constructive work, such as the determination of the proper tolerance in the pitch, diameter, and angle of machine screws, taps, dies, micrometer gauges, etc. It is a matter of common knowledge that the main difficulty in the manufacture of ammunition and guns by the countries now at war has been the impossibility of securing the necessary tools of this character.

Volumetric Glassware and Hydrometers.

There were 1,369 pieces of volumetric glassware submitted for test during the year, consisting of Babcock bottles, burettes, cylindrical graduates, flasks, specific gravity flasks, measuring pipettes, transfer pipettes, and special apparatus. Of this number, 171 pieces were rejected on preliminary examination and 1,198 pieces were tested, of which 914 pieces, or 67 per cent of the total submitted, passed.

In cooperation with the committee on tolerance and specifications of the National Conference on Weights and Measures, tolerances and specifications for glass graduates used in the drug trade were prepared and adopted by the conference in May, 1916, and also by the State of Wisconsin. It is expected that they will be generally adopted by the State departments of weights and measures throughout the country.

Of the 1,138 hydrometers submitted during the year, 949, or 83 per cent, passed the test.

Density.

The number of density determinations made during the year was 220.

An investigation of the relation between concentration and density of aqueous solutions of copper sulphate and sulphuric acid was carried out in cooperation with the division of chemistry and the results were published as Scientific Paper No. 275. The information obtained is of use to electrotypers and electroplaters in the regulation of their electrolytes.

An investigation of the density and thermal expansion of cottonseed oil was made in cooperation with the division of optics, at the request of the Society of Cotton Products Analysts. The information obtained will be of value in the standardization of methods for determining the purity of cottonseed oil.

Work has been commenced on an investigation of the density of aqua ammonia of various concentrations, in connection with the extended investigation of refrigeration constants being carried on by the division of heat and thermometry. The density work is hardly more than well under way and no definite results can be reported at this time.

Testing of Watches.

During the year 48 watches were submitted for test, an increase of 18 over the number submitted the previous year. All of these were submitted in class A, and 50 per cent of the number passed the requirements and received a class A certificate. Of the 24 watches receiving certificates, 22 were of American make. In addition, a number of other watches were tested for experimental purposes, including chronograph watches, and some progress was made in studying the average performance of the cheaper grades of timepieces.

Tuning Forks.

Some equipment has been purchased for the test of tuning forks, and other apparatus has been ordered. One tuning fork, for use in ordnance tests, has been standardized for the Government, and requests have been received for the test of other forks for similar purposes. This line of work will be extended as soon as possible.

Barometry.

During the fiscal year 5 mercurial and 58 aneroid barometers were tested, the number of aviation instruments submitted having markedly increased over the previous year.

Attention has been given to the improvement of the methods of testing aneroids, both in order to simplify the routine and to better adapt the tests to particular classes of instruments, without, however, departing from the fundamental principles afforded by the investigations previously reported.

Testing of Laboratory Gas Meters.

Ten laboratory gas meters have been calibrated for commercial firms, and in addition a considerable number of meter calibrations have been performed for various sections of the Bureau.

Investigation of Different Types of Meter Provers.

An investigation of several different types of gas-meter provers has been carried out during the past 10 months. The object of the investigation was to determine the advantages of the various types, especially with regard to the accurate tests of meters, and to discover the methods of operation best suited to each type. The investigation yielded a considerable amount of useful information, which is being prepared for publication.

Auxiliary Scale for Meter Prover.

The investigation of different types of meter provers also resulted in the development of an auxiliary prover scale, by means of which the ease and accuracy of reading the ordinary meter-prover scale is considerably increased.

Cubic-Foot Apparatus.

A number of types of cubic-foot apparatus, such as are used principally to calibrate meter provers, were the object of experiments, which led to important conclusions concerning the best methods of use of this apparatus and the relative merits of the different types.

A new portable type of cubic-foot apparatus has been devised. The cubic-foot apparatus at present in use is extremely cumbersome, whereas the new apparatus can be easily carried about by one man and, therefore, should be of special value in the State inspection of meter-testing apparatus. Certain features of the apparatus also render it more convenient and accurate for the calibration of meter provers than the types commonly used at present. A patent, dedicated to the public, is being applied for on the instrument.

Standard-Screen Scale.

A conference was held at the Bureau in April on the subject of a standard-screen scale suitable for sieving tests in the various industries. Representatives of different engineering and technical societies interested were present, as well as manufacturers of sieves and several important users. A screen scale proposed by the Bureau, based upon an opening of 1 mm. width and using the square root of 2 as the ratio of the openings of successive sieves to one another, was tentatively adopted, subject to slight modifications to be made by a committee appointed for the purpose, and it is expected that the screen scale in its final form will soon be ready for publication. Its adoption by the various engineering and technical societies would unify the results of sieving tests and reduce the varieties of sieves required for such work.

Inspecting and Testing Scales.

At the request of the Post Office Department, this Bureau undertook the inspection and test of 1,200 automatic scales, each having a capacity of 50 pounds, for use in the parcel post service, the contract for which had been let to a scale company located in Chicago. This work was of particular importance, since the type of scale was a new one, having been devised particularly for parcel-post work, and many of the details had been left to be worked out while the scales were being built. A large amount of work was done along these lines, which resulted in the improvement of the scales produced over the model at first submitted. The greatest care had to be taken during the entire contract to see that the workmanship, details of construction, and accuracy were maintained, since these were of importance if satisfactory scales were to be procured. It is believed that this object was accomplished by the inspection.

A series of tests were made on scales at the Philadelphia post office, on the request of the Fourth Assistant Postmaster General, and it is believed that the information offered in the report submitted to him should be of great service to his department in the maintenance, operation, and repair of scales in the post-office service.

Fifty coin scales were tested for the Post Office Department, and a report was submitted calling attention to the unsuitability of the type for the purpose intended.

Fifty 600-pound capacity platform scales were tested at the factory at Bennington, Vt., for the Post Office Department.

A number of postal scales in use in the post office at Gardner, Mass., were tested by a representative of the Bureau.

Work was done with representatives of the Post Office Department in the formulation of specifications for the portions of the Post Office Department supply schedule relating to weighing scales and weights.

An analytical balance having a chain device for the determination of small weight values was tested, at the request of the Internal-Revenue Service, in Washington, and the faults found were corrected.

A tramway scales at the National Soldiers' Home in Virginia was tested and a report made recommending the installation of a scale more suited to the work at that point.

About 100 scales of various capacities have been tested during the year for the Navy Department at the navy yards or naval stations at Washington, D. C.; Indianhead, Md.; New York City; Norfolk, Va.; Key West and Pensacola, Fla. In connection with the work done at two of these points, reports were submitted, giving in detail the equipment and organization necessary for the maintenance, testing, operation, and purchase of weighing equipment throughout the establishments. At the Norfolk Navy Yard and also at the Naval Proving Ground at Indianhead an employee was instructed in the procedure and in the various details requisite for the repair and adjustment of the principal types of scales in use at these points.

Testing of Railroad-Track Scales.

During the past fiscal year important progress has been made in the work of testing railroad-track scales. Not only is the work carried out directly by the Bureau of great value, but the Bureau is also an important factor in maintaining the lively interest which the subject continues to command and which has resulted in very distinct progress during the past year. The active interest taken in this subject has made it necessary for the Bureau to limit the work to railroad-track scales and postpone the testing and study of other large scales, such as grain-hopper scales, the correctness of which is absolutely essential to the grain industry.

The Bureau has been cooperating in this work with the State and municipal weights and measures officials, with weighmasters, manufacturers, railroads, private individuals, and other departments of the Federal Government, and steady progress is being made toward securing adequate standards in railroad-track scale testing.

Location and Condition of Track Scales Tested.

Tests have been made in Alabama, California, Colorado, Connecticut, District of Columbia, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Jersey, New York, North Carolina, Oregon, Rhode Island, South Carolina, Texas, Tennessee, Utah, Virginia, West Virginia, and Washington.

In these States 325 scales have been tested, of which 201, or 61.8 per cent, failed to pass the tolerance in the condition in which they were found. The tolerance used by the Bureau is based on a maximum permissible error of weighing of 200 pounds in weighing a car of 100,000 pounds gross weight.

In addition to these scales, one four-section master scale and nine two-section master scales were tested. These scales have been constructed and installed with special care for the purpose of securing high accuracy and reliability for standardizing the test cars used by the railroads in the routine testing of railroad-track scales. Two of

the 10 master scales tested were found within the tolerance upon test, 5 were adjusted within the tolerance during the test, and the remaining 3 were not in a condition to make their adjustment within the tolerance practical. The tolerance applied for these scales corresponds to an error of 10 pounds in a load of 100,000 pounds.

The testing of master scales represents a highly important phase of the work, as it is through their agency that the standards of large denomination are made available for the routine testing of track scales by States and railroads.

While the number of tests made is about the same as for the preceding year, the work of the fiscal year just closed represents a very appreciable extension of the work. The master scales tested were located at widely separated points, so that considerable time was required to cover the territory outlined.

Reports on Scales Tested.

Reports on the scales tested, giving detailed results of the tests, have been rendered to the States which have organized departments of weights and measures and to the owners of the scales or to those responsible for their test and maintenance. The acknowledgments of these reports indicate that they are carefully studied and that the recommendations of the Bureau are generally carried out, resulting in many instances in the installation of new scales.

Purchase of Test Cars and Master Scale.

During the past fiscal year an all-steel test-weight car of the same type as the one already in use has been added to the equipment. This test car has been very valuable in extending the tests and in avoiding interruptions in the field work. A master scale of 100,000 pounds capacity and two simple test cars, each consisting of a cast-iron body mounted on a short wheel base, have been ordered and will be added to the equipment during the coming year. These two cars are entirely different from the other test cars used by the Bureau, as explained below. The master scale will be installed near Washington, where it will be used to standardize the two test cars just mentioned and to test the accuracy of cars used by the railroads. The two test cars are of the latest design of simple cars of practically invariable weight, and are suitable for routine testing of track scales in the territory accessible to master scales. One car will weigh 40,000 pounds and the other 80,000 pounds, and together they can be used for a certain class of testing in place of one of the master test cars, which can be used for other important work, such as testing master scales. These new cars will also aid the Bureau in studying at first hand the matter of routine testing of track scales with an equipment which corresponds to that in use by the railroads.

Linear Expansion of Materials.

During the year just closed a high-pressure air line was installed, connecting the expansion apparatus with the air compressor in the low-temperature building. Air is delivered at a pressure of about 2,000 pounds per square inch and is expanded to atmospheric pressure in the oil bath, thus affording a means of cooling to liquid-air temperatures. Pentane is used as a bath when these low temperatures

are reached. So far it has been impossible to cool below —150° C., owing to minor defects in the apparatus, which will soon be remedied.

Light may be thrown on some important physical properties of materials by investigating their behavior at very low temperatures. For instance, by studying the behavior of some of the nickel steels from —150° C. to higher temperatures, it may be possible to determine a method of stabilizing the alloy. Several tests calling for a temperature of —30° have already been requested.

The most important expansivity research undertaken during the year was in cooperation with one of the steel companies on American invar. Specimens of nickel steel of various compositions and heat treatment were submitted for thermal expansivity tests and, at the same time, magneto-striction measurements were made on them. It is expected that this work will be published in a Bureau scientific paper during the calendar year.

In connection with the work on nickel steel, the Bureau endeavored to secure an alloy steel of such a composition that its coefficient of expansion would be approximately equal to that of the American porcelain used for insulators of the high-voltage type. It is believed that the substitution of such an alloy for the iron used in the caps of the high-voltage insulators will prevent a great many of the failures due to the cracking of the porcelain. Many samples of American porcelain were tested in this connection, and a nickel steel was finally found which has approximately the same coefficient of thermal expansion as the porcelain.

A joint research on some manganese bronze has been undertaken with the division of metallurgy, in order to determine the cause of this material cracking under conditions found in its practical uses. Only two specimens have thus far been tested. The temperature range of the test extends from 0° to 600° C.

A research was carried on in order to determine more fully the expansivity of a certain kind of glass. It was found that it has a coefficient of expansion of about one-third of that of ordinary glass, allowing it to be used in the arts and sciences where moderately high temperatures and sudden changes of temperature are encountered, taking the place of such materials as porcelain, earthenware, etc., as in cooking utensils.

Liquid-Measuring Pumps.

A careful study of the design, construction, installation, and conditions of use of liquid-measuring pumps was made, accompanied by a considerable number of field tests under actual operating conditions. These pumps are in very wide use by garages and motor-supply dealers for the dispensing of gasoline and lubricating oils, and the high price of these commodities, especially the former, is a factor in making the accuracy of the pumps used a matter of primary importance. A determination was made of the height of suction lift at which rapid vaporization took place for a number of commercial grades of gasoline, this factor being of great importance in deciding what height it may be allowable to lift gasoline on the suction side of measuring pumps.

A paper on the results of this analysis and investigation was prepared and read before the Eleventh Annual Conference on Weights

and Measures, in May. The paper will later be published as a Bureau technologic paper.

Magnetic Damping of Mercury.

An electromagnetic method of damping waves and other disturbances in mercury in barometers and other measuring instruments has been devised, and experiments have been made to show its effectiveness. It is believed that the method will be found especially useful in increasing the accuracy of certain measurements which must be made at sea or in other places where the foundations of the instruments are unsteady. A Bureau scientific paper treating of the method will be published.

Theoretical Work on Elasticity.

Some general relations governing the stiffness of elastic systems have been developed mathematically in order to provide a rational basis for designing instruments whose action depends on the deformation of some form of spring. This work was started in order to fix reasonable rejection limits on aneroids subject to temperature errors, but the results are not limited to the aneroid. Experiments have been begun to supply the necessary constants, which depend on the material.

Standard-Barrel Act.

The act of March 4, 1915, establishing standard barrels for fruits, vegetables, and other dry commodities became effective July 1, 1916. This law provides that rules and regulations shall be made by this Bureau and approved by the Secretary of Commerce. A wide range of commodities is affected by this act, and a very large amount of work has been done in investigating the industries affected by the terms of the law to determine whether they came within the exemptions stated. The lime industry was able to demonstrate that a standard-weight barrel would be more equitable to their trade, and, as a result the Bureau assisted the National Lime Manufacturers' Association in framing a proper bill to regulate this industry and appeared before the committees of Congress having the bill under consideration and advocated its adoption. This bill has passed both branches of Congress and is now in conference. The closest attention has been given to all these matters, since it is the earnest desire of this Bureau to have the law adequately enforced with as little hardship and loss to those affected as possible, and this end has constantly been kept in mind.

The question of establishing proper tolerances and variations under the act has also been given very careful consideration. With a view to getting information first hand in regard to the practical limitations existing in the manufacture of barrels of definite sizes, and for the purpose of studying the methods of packing barrels and the general conditions influencing the quantity of commodity which a barrel may contain, representatives of the Bureau visited the eastern part of Virginia, where the manufacture of barrels is extensively carried on and where very large quantities of vegetables are shipped in barrels. This investigation has been productive of very satisfactory results in the particulars mentioned and has revealed the fact that there is a general desire on the part of those affected by the

law to comply with its provisions. This has been strengthened by a realization on their part that the Bureau desires to assist them in every way possible.

The rules and regulations under this act are nearly completed, and it is expected that they will be issued shortly.

Annual Conference on Weights and Measures.

The Eleventh Annual Conference on Weights and Measures, held at the Bureau of Standards on May 23 to 26, inclusive, was attended by 84 weights and measures officials, representing 21 States, the District of Columbia, Porto Rico, the Philippine Islands, and 55 cities and counties. There were also present 56 persons representing manufacturers of weights and measures, railroads, etc.

A number of papers of great practical value to weights and measures officials were presented, and there were many valuable discussions on important phases of the work. Much interest was manifested in the meeting.

Tolerances and Specifications.

As an example of the constructive work accomplished by the conference may be mentioned the tolerances and specifications for weights and measures and weighing and measuring devices, which were again considered, with the result that a few amendments recommended by the committee were adopted. These amendments consisted in a large measure of adding two new classes of apparatus not heretofore regulated, namely, prescription balances and scales and glass graduates. Both of these additions were very necessary, since several States have begun the work of inspection on these classes of apparatus, and the preliminary surveys reveal chaotic conditions which should be remedied. The States which had started the work were in great doubt as to proper tolerances and specifications to be applied, while other States were merely waiting to inaugurate the work until tolerances and specifications should be promulgated. The remainder of the amendments consisted largely in broadening the scope of specifications, making some which had heretofore been applicable only to special classes of apparatus apply to all classes.

Experience based on observation of the enforcement of these tolerances and specifications in various jurisdictions has demonstrated that they have developed into a code well adapted to the improvement of the condition of the apparatus in use throughout the United States, and that they can be enforced without injustice or without unnecessary disturbance of existing types. This Bureau has always been in sympathy with this work and has cooperated in it. The Bureau feels satisfied that it is in satisfactory form and, consequently, is preparing the matter to be issued as a circular of the Bureau instead of as a special publication of tolerances and specifications as heretofore. Such uniformity as exists among the States at the present time is due to the issuance of these tolerances and specifications in this form, and a still greater measure of uniformity is confidently expected in the future. At the same time it has been demonstrated that perfect uniformity will never prevail under the present system of having each State and a number of cities independently issuing tolerances and specifications, since disagreements are bound to exist. The Bureau is receiving letters from manufacturers

asking relief from the conditions as they exist, but is unable to help them materially at this time. The Bureau believes that conditions will never be wholly satisfactory until the Government is given power by Federal legislation to issue tolerances and specifications which will be uniform and apply throughout the entire country. A great majority of the State officials are firmly committed to this idea and are hoping that action will be taken by Congress to put this power in the hands of a Government bureau, which will then be able to regulate the entire matter.

Information Furnished.

Numerous technical inquiries pertaining to weights and measures were answered during the past fiscal year, of which the following are briefly mentioned to indicate the type and scope of these requests: Opinion on design of a new form of test weight for testing cotton scales; theory of design of automatic package-filling scales; the formulation of examination questions for State and city weights and measures examinations; the design of springs for spring scales which shall be self-compensating for the effects of temperature; relative adaptability and accuracy of two different types of scales for a definite purpose; information relative to the manufacture of a balance for the approximate analysis of solder; inquiries as to the proper method of testing a paper scale; inquiries as to names and authors of books on weights and measures subjects and the names of weights and measures officials; opinion on the relative merits of two wagon scales offered by contractors under a certain specification.

A new design of lever balance was offered for examination by an inventor, and an opinion was given him as to its utility and as to the methods which might best be followed in its development.

In addition to the assistance given weights and measures officials throughout the country through the meetings of the Annual Conference on Weights and Measures, heretofore mentioned, and the publications emanating therefrom which are issued under the auspices of the Bureau, very valuable assistance has been rendered by the Bureau through replies to the large number of inquiries received from all parts of the United States affecting practically all phases of weights and measures work. For example, in several of the States there is no organized department of weights and measures under a State official and, consequently, the local official has no one in his State to whom he can apply for authoritative information. As a result, the Bureau receives a large number of inquiries from newly appointed officials who have little or no knowledge of the duties of their offices and supplies them with information of a practical character which enables them to carry on their work with a degree of efficiency which otherwise could be attained only after years of experience. It is the aim of the Bureau to render every possible assistance to all weights and measures officials and to be a clearing house of information on all phases of their work.

Several new density and volumetric tables were calculated for the revision of the United States Pharmacopœia and a new alcohol table for Bulletin No. 107 of the Bureau of Chemistry (Official and provisional methods of analysis). The last-named table is based on work done at the Bureau of Standards (see Scientific Paper No. 197)

and will replace the alcohol table of Gilpin, Drinkwater, and Squibb, based on work a part of which was done about 125 years ago.

Much information has been furnished in regard to the density, weight per gallon, weight per cubic foot, etc., of various substances.

One case that might be specially mentioned is that of the specific gravity of beechwood creosote, which was sold on contract as being in conformity with the United States Pharmacopœia requirements as to specific gravity. On a contract involving about $12,000 the purchaser declined to accept the goods on the ground that they did not meet the United States Pharmacopœia requirements. The matter was referred to the Bureau for a decision, and tests showed that the material was actually slightly below the United States Pharmacopœia requirements.

During the past fiscal year information has been furnished in answer to a number of inquiries with regard to various standards for screws, bolts, and nuts and with regard to size of wire and sheet-metal gauges. A large number of such inquiries were made with regard to screw standards or wire gauges of foreign origin or in use in foreign countries. There is considerable dissatisfaction with the general wire-gauge situation, the existing large number of wire and sheet-metal gauges leading to frequent confusion. Some manufacturers and some industries have succeeded in solving the problem for their own purposes by using one gauge exclusively. Such concerns are generally opposed to the adoption of a single-standard gauge other than the one they themselves use. However, a single wire and sheet-metal gauge is generally admitted to be desirable.

Three representatives of a large dental company spent two days at the Bureau to obtain assistance in devising a method for measuring the gradual changes in volume that take place during the setting of amalgams and cements used in filling teeth. These measurements were required in order to produce alloys and cements that would neither expand and produce pain from pressure in the cavity nor contract and admit bacteria. The measuring apparatus which had answered the requirements of 5 or 10 years ago was not sensitive or reliable enough for the high-grade alloys now produced. Before the visitors left the Bureau a simple device was constructed and given a preliminary test which indicated a thoroughly satisfactory solution.

Considerable correspondence in regard to the measurement of the relative humidity of the atmosphere has been received and answered by the Bureau during the year.

Several papers relating to technical matters of scale installation and tests and other phases of weights and measures work have been prepared and given before representative organizations of weights and measures men. These papers were very well received and have been printed in various technical journals interested in the subjects discussed.

Publications on Weights and Measures Subjects.

During the fiscal year just closed the following publications have been issued: Circular No. 57, U. S. Standard Tables for Petroleum Oils. The demand for this publication was such that a second edition was necessary almost immediately. Oil men throughout the country appear to find this a very useful circular. Circular No. 58, Invar and Related Nickel Steels, was prepared in cooperation

with the division of metallurgy. Circular No. 59, United States Standard Baumé Hydrometer Scales, was issued with a view to correcting certain erroneous impressions in regard to the Baumé scales in use in the United States. Assistance was rendered the electrical division in the revision of Circular No. 48, Standard Methods of Gas Testing. Portions of Circular No. 55, Measurements for the Household, were prepared by the weights and measures division. Circular No. 9, Testing of Glass Volumetric Apparatus, and Circular No. 16, on The Testing of Hydrometers, have been revised with slight changes, and Circular No. 19, Standard Density and Volumetric Tables, has been revised and considerably enlarged by the addition of several new tables. Technologic Paper No. 77, The Density and Thermal Expansion of American Petroleum Oils, gives an account of the experimental work on which the tables in Circular 57 are based. Another paper issued is Scientific Paper No. 275, Relation Between Composition and Density of Aqueous Solutions of Copper Sulphate and Sulphuric Acid. A circular on railroad-track scales was prepared in preliminary form, in order that criticisms and suggestions could be received and considered in the printed edition of the circular. A circular on master scales also was prepared in preliminary form and will be distributed to those interested for criticisms and suggestions.

Metric System.

A rapidly increasing number of requests have been received for information as to the metric system. These are from schools, scientific institutions, and manufacturing firms who use or desire to use the metric system in connection with the preparation of products for export to metric countries. In a number of cases manufacturers are making their products for export and for domestic trade as well in metric sizes. Owing to the many references in the daily press in regard to international affairs, the public is becoming better informed and is demanding a large amount of information regarding the system. The Bureau has, therefore, issued a descriptive pamphlet which contains a statement of the system, a circular containing tables of equivalents useful in converting units from one system to the other, and a graphic chart of the metric system for schools. The great demand for these publications indicates a widespread interest in the subject.

2. HEAT AND THERMOMETRY.

[Temperature, heat, heat constants, melting and boiling points, critical points, specific heats, conductivities, and other thermal properties of materials, including researches on heat units and standard temperature scales, standardization of instruments and methods for measuring temperature, determination of refrigeration data and the fire-resisting properties of materials and other experimental work of specific value to the refrigerating and heating industries, in the manufacture of thermal appliances, in scientific testing and laboratories, in fire-safety engineering, and in the industries and sciences requiring precise knowledge of temperature measurements and heat constants.]

Low-Temperature Scale.

Some progress has been made during the year on the establishment of the low-temperature scale. The freezing point of mercury, referred to below, was determined. Some work has been done toward calibrating a number of platinum resistance thermometers at low

temperatures. An apparatus containing pure oxygen and of such form that the vapor pressure of the oxygen may be measured (improved form of Stock's thermometer) has been constructed.

It is highly desirable that more time and apparatus should be made available for the low-temperature investigations. The Bureau should undertake a gas-thermometer investigation in the interval 0° to —200° C. At present the low-temperature scale available to the Bureau is dependent on the results published by one experimenter.

The Freezing Point of Mercury.

On account of its importance as one of the fixed points of the temperature scale, a careful determination was made of the freezing point of mercury. Nineteen determinations were made on three samples of mercury purified by different methods. Three platinum resistance thermometers having resistances in melting ice of, approximately, 2.5, 10, and 25 ohms, respectively, were used. Resistance measurements were made both by the Wheatstone bridge method and the potentiometer method.

The final result of all the measurements gave for the freezing (or melting) point of mercury —38.873° C. The maximum deviation of any determination from the mean was 0.005°

Depression of the Ice Point of Thermometers.

When a mercury-in-glass thermometer is heated, the glass expands to its final equilibrium condition corresponding to the higher temperature in a comparatively short time (some minutes). When the thermometer is again cooled to its original temperature, the glass slowly contracts and only attains its original volume after weeks and months. This "after effect" in glass, different for different kinds of glass, results in the "depression of the ice point" and has a most important bearing on the method of use of mercury-in-glass thermometers. A large number of observations were made during the year on the ice-point depressions and rates of recovery of the ice points of thermometers made of different kinds of glass, under different conditions of use.

Method of Testing Clinical Thermometers.

The Bureau now has under contemplation a radical change in the method of certification of clinical thermometers. Instead of issuing a certificate giving the corrections at four points of the scale (viz, 96°, 100°, 104°, and 108° F.), as has been done heretofore, it is proposed to issue a "blanket certificate" for all thermometers the corrections for which do not exceed 0.1° F. at the normal point and 0.2° at 104° F., the certificate for such a thermometer simply stating that "the thermometer has been compared with the standard thermometers of the Bureau and has been found to be without significant error."

A circular letter on the proposed method of testing and certifying clinical thermometers has been sent to several hundred physicians and surgeons in our leading hospitals and medical schools and to practically all the manufacturers of clinical thermometers, and the replies so far received are unanimous in favor of the proposed method. It is probable, therefore, that steps will be taken during the present fiscal year to put the proposed method into use.

Wheatstone Bridges and Some Accessory Apparatus for Resistance Thermometry.

During the past five years the Bureau has frequently been called upon to assist in the design of resistance thermometers and accessory apparatus, and these designs also have been used in the construction of apparatus for the Bureau. A description of the types of apparatus that have proven most useful has been prepared and is now in press. As a result of these developments, apparatus for accurate measurements with resistance thermometers may now be obtained at a cost sufficiently low to make it available to industrial laboratories, educational institutions, etc., whose resources are somewhat limited. The Bureau has issued several publications in past years on apparatus of this kind designed for temperature measurements of the highest attainable accuracy.

Experimental Conditions Affecting the Sulphur Boiling Point.

An extensive investigation of the experimental conditions affecting the sulphur boiling point was undertaken, in order to answer, if possible, some questions that had not been definitely disposed of by the work of previous investigations. The importance of the sulphur boiling point as a means of establishing the temperature scale has been emphasized in several of the Bureau's publications. The effects of varying the size, form, and material of the radiation shields and of varying the size, form, surroundings, and manner of heating of the boiling tube were investigated, as well as the effects due to varying the material of the protecting tube of the thermometer. An improved type of sulphur-boiling-point apparatus was designed, built, and tested. Either gas or electric heating may be used, and both have proven satisfactory.

A redetermination of the change with temperature of the vapor pressure of sulphur over a pressure range of 700 to 800 mm. was also undertaken, using an improved type of "artificial atmosphere." The results are in agreement with accepted formulas, but show that the accuracy of the formulas was greater than that of the data from which they were determined. As the result of this work the Bureau will be able to formulate more definite specifications for the use of the sulphur boiling point as a standardization temperature.

The excellent results obtained in the determination of the vapor-pressure temperature relation for sulphur makes it desirable to extend this work to other substances, notably naphthalene, benzophenone, and anthracene, the boiling points of which may be used in defining the temperature scale. If pure materials could be obtained this work could probably be undertaken during the coming year.

Accuracy in Calorimetric Temperature Measurements.

In connection with routine tests of resistance thermometers and of differential calorimetric thermocouples, some special tests were made of the precision attainable in the use of such apparatus in calorimetry. For this purpose two sets of apparatus were used simultaneously to measure the rise of temperature in a calorimeter. The results of a series of such experiments indicated that the three equipments used—viz, the Bureau's regular resistance thermometer equipment, a resistance thermometer equipment conforming to specifications furnished by the Bureau and put on the market by an

American instrument maker, and a calorimetric multiple thermocouple designed and constructed by the geophysical laboratory of Washington—all gave results in agreement to about 1 part in 10,000.

Calorimetry.

The subject of heat measurements by means of the calorimeter is one of great scientific and industrial importance.

The publication by the Bureau of Technologic Paper No. 36, on Industrial Gas Calorimetry, and of Circular No. 48, Standard Methods of Gas Testing, has resulted in greatly increasing the demands on the Bureau for the testing of gas calorimeters, of which 18 were tested during the year for gas companies, municipalities, and public-service commissions.

Two calorimeters of the bomb type were standardized, one for a coal company and one for a municipal laboratory.

Some work has also been done on modifying and standardizing the Dewar flask calorimeter used some five or six years ago for the determination of the specific heats of calcium-chloride brines, with a view to its use for the determination of the specific heats of sodium-chloride brines.

An investigation that has been carried forward from year to year is that relating to the determination of the heating values of the more important elementary gases that enter into the composition of natural and manufactured gases. But little progress was made on this investigation during the past year. It is to be hoped that assistance can soon be provided so that this important investigation can be completed.

Other important calorimetric investigations have been carried out during the year on the determination of the specific and latent heats of anhydrous ammonia in connection with the investigations on refrigeration constants, referred to later in this report.

Standard Heat Samples for Use in Calorimetry.

Samples of benzoic acid, naphthalene, and cane sugar are now regularly sent out by the Bureau as standard heat samples and are widely used by chemists and engineers for the standardization of the calorimeters used for testing the heating values of fuels, foods, etc. Two hundred and fifty-seven of these standard heat samples were furnished during the year to numerous industrial plants using large supplies of fuel, such as cement, steel, cotton, and paper mills; coal, oil, and gas companies; electric power companies; chemical manufacturing plants; as well as to university, technical, municipal, State, and national testing laboratories and bureaus.

The experimental work describing the method followed at the Bureau in determining the heat of combustion of these standard samples with the highest attainable accuracy is fully set forth in Bureau of Standards Scientific Paper No. 230 and the method of using the samples for the standardization of bomb calorimeters in Bureau of Standards Circular No. 11.

The Bureau has been greatly handicapped during the year through the failure to obtain on the market benzoic acid of satisfactory purity for use as standard heat samples, using the present known methods of purification of the stock sample.

Standard Melting-Point Samples.

In the annual report for 1913–14 it was recommended that a number of metals and salts, of accurately determined melting points, should be certified by the Bureau and supplied to technical men to enable them to conveniently check the accuracy of their pyrometers, just as the standard heat samples now furnished by the Bureau serve to check the accuracy of heating-value tests. By a careful conservation of appropriations and time available for new work this recommendation now seems within reach of realization. During the past year the Bureau has secured a supply of several hundred pounds each of especially pure samples of copper, aluminum, and zinc, which will be available for distribution as standard melting-point samples as well as for use in the determination of the fundamental physical constants of these materials. The Bureau is especially indebted to the Raritan Copper Works, Perth Amboy, N. J.; the Aluminum Co. of America, Pittsburgh, Pa.; and the New Jersey Zinc Co., Palmerton, Pa., for their valuable cooperation in making available to the Bureau especially pure samples of these metals.

The special resistance thermometers required for the determination of the melting points of these samples have been completed and standardized, and the melting-point determinations on zinc and aluminum have been practically completed. Standard melting-point samples, numerous requests for which have been received in the past, will probably be ready for distribution some time during the fiscal year 1916–17.

Characteristics of Radiation Pyrometers.

The experimental work incident to this investigation was completed during the preceding year and was quite fully reviewed in the last annual report. The publication describing the work, Bureau of Standards Scientific Paper No. 250, came from press early in the year and contains a discussion of the principles of radiation pyrometry and descriptions of the usual types of these instruments, their calibration, errors, methods of use, and applications.

Radiating Properties of Metals and Oxides.

For a number of years, as time permitted, there have been carried on investigations on the radiating properties of substances at high temperatures. This information is necessary to interpret the readings of optical and radiation pyrometers, which are coming into extensive use in various industrial operations. Several papers on this topic have been published by the Bureau in recent years (Bureau of Standards Scientific Papers Nos. 55, 121, 224, 242, 243, 249).

During the past year some further work has been done on the monochromatic emissivities of graphite and of molten copper.

Effective Wave Length of Transmission of Color Screens.

The "effective wave length" of transmission of a color screen, of great importance in the accurate measurement of high temperatures by optical methods, is defined mathematically. The difference of the value of this wave length from that defined by the "center of gravity" of the luminosity curve is shown and a simple and accurate method is given for determining the effective wave length. A short preliminary paper under the above title has appeared in the Journal of the Washington Academy of Science, 1915, Volume V, page 526.

A New Relation Derived from Planck's Law.

Planck's law gives the intensity of radiation corresponding to each wave length throughout the spectrum of a black-body radiator when its absolute temperature is known.

A paper under the above title was published in the Bulletin of the Bureau of Standards, 1916, Volume XII, pages 479–482 (Bureau of Standards Scientific Paper No. 259). A short paper on the same subject appeared in the Physical Review, February, 1916. It is shown that the product of the absolute temperature and the value of the wave length corresponding to the "center of gravity" of the spectral energy curve of a black body is a constant of the following form, $\theta\lambda_c=0.37021\ c_2$, where c_2 is the well-known constant of the Planck equation.

Pyrometer Color Screens and the Extrapolation of the High-Temperature Scale.

A paper under the above title was published in the Bulletin of the Bureau of Standards, 1916, Volume XII, pages 483–501 (Bureau of Standards Scientific Paper No. 260). A new method for determining the "effective wave length" of the color and absorption screens used in optical pyrometry is derived and applied to several specific screens and glasses. The shift of effective wave length with change in temperature of the source and the effect this shift may have on the accuracy of temperature measurements are discussed. It is shown both theoretically and experimentally that for precise work at high temperatures with pyrometers using color screens, a thorough knowledge of the change of effective wave length with temperature is required. Errors amounting to 50° may occur in extrapolating the scale to 3,500° C. unless this fact is considered.

The Illumination from a Radiating Disk.

A paper under the above title was published in the Bulletin of the Bureau of Standards, 1916, Volume XII, pages 583–586 (Bureau of Standards Scientific Paper No. 263). A complete solution is given for the illumination produced by a diffusely and uniformly radiating circular disk at any point in space on a surface parallel to the disk. The correct solution is shown to be just as convenient to use as many of the approximate solutions appearing in the technical journals. The matter considered in this paper is of some importance in illumination engineering.

A Misconception of the Criterion of Gray-Body Radiation.

A body is said to emit gray radiation when the ratio of the intensity of its radiation, at a given wave length and temperature, to that of a black body at the same wave length and temperature, is constant throughout the spectrum.

A preliminary note on the above subject was published in the Journal of the Washington Academy of Science, 1916, Volume VI, pages 193–197. This note points out that the conclusions of Elisabeth Benedict in regard to the criterions for gray-body radiation are incorrect. It is shown that even though the so-called logarithmic isochromatics of various wave lengths for nonblack radiators do intersect in one common point, this point of intersection is no immediate indication of the true temperature of the nonblack radiator and is no proof that the radiator is even approximately gray.

The Relation Between Color Temperature, Apparent Temperature, True Temperature, and Monochromatic Emissivity of Radiating Materials.

A paper under the above title was published in the Journal of the Washington Academy of Science, 1916, Volume VI, pages 317–323. The relation between the above quantities are derived for the first time and are found to agree excellently with the available experimental data. The exact definitions of and the relations between these quantities are of fundamental importance in photometry and optical pyrometry.

Luminosity of a Black Body and Temperature.

A paper under the above title was published in the Bulletin of the Bureau of Standards, 1916, Volume XIII, pages 137–145 (Bureau of Standards Scientific Paper No. 270). The relation between luminosity and temperature of a black body has been derived by a new method. The Rasch equation is shown to be unsatisfactory, while the Nutting equation, or a slight modification of that equation, holds exceedingly well. The exact meaning of the Crova wave length is defined and is shown to be of the form $\lambda_L = a + b/T + c/T^2$, where λ_L=wave length, T=absolute temperature, and a, b, c, are constants.

This question of the relation between luminosity and temperature, aside from its important bearing on problems in the field of high temperature measurements, is receiving international attention at the present time in connection with fundamental problems in light measurement, especially in the attempt to find some satisfactory standard of light.

Luminosity and Temperature of Metals.

A short preliminary paper under the above title was published in the Journal of the Washington Academy of Science, 1916, Volume VI, pages 323–326. An equation is derived giving the relation between luminosity and temperature of a nonblack body. This has been applied for the computation of the melting point of tungsten from Langmuir's determinations of the luminosity of solid tungsten at its melting point. The value of 3,712° absolute is obtained on the basis of Hyde, Cady, and Forsythe's measurements on the color temperature, true temperature, and apparent temperature of tungsten. If Langmuir's values for the emissivity are used, the melting point is found to be 3,660° absolute. Both of these values are computed on the basis of c_2=14450 and upon Hyde, Cady, and Forsythe's values of the luminosity of a black body at various temperatures.

The Temperature Coefficient of Pyrometer Absorption Classes.

This investigation is a continuation of Bureau of Standards Scientific Paper No. 260, Center of Gravity and Effective Wave Length of Transmission of Pyrometer Color Screens and the Extrapolation of the High Temperature Scale. It was shown in the latter paper that the so-called "constant" of a pyrometer absorption glass of the usual type increases with increasing temperature of the source sighted upon. This fact was only qualitatively confirmed by experiments, but an exact quantitative confirmation was not possible at that time. A method has since been devised for testing this point.

A tungsten lamp or an acetylene flame illuminating a diffusing screen was used as a luminous source. Such a source emits, in the visible spectrum, radiation of the same spectral distribution and intensity as that emitted by a black body at the "color temperature" of the screen and when viewed through a sector disk of proper angular opening. The "constant" of the absorption glass obtained with such a luminous source has a definite relation to the "constant" obtained with a black body source at the corresponding "color temperature." The conclusions arrived at in the previous paper (Bureau of Standards Scientific Paper No. 260) were confirmed. It was also found that the "constant" of the absorption glass changes with room temperature. Preliminary readings were taken over a temperature range 30° to 95° C.

This investigation makes available a laboratory method of completely calibrating pyrometer absorption glasses and makes possible the extrapolation of the optical temperature scale to very high temperatures without introducing the errors hitherto present in all such temperature measurements in which absorption glasses were used.

The results of this investigation will be prepared for publication during the next fiscal year.

Other High-Temperature Investigations.

(*a*) The monochromatic emissivity of graphite and the monochromatic emissivity of copper have already been referred to in this report.

(*b*) Some work has been done on the effect of mounting thermocouples in thick conducting iron tubes projecting into furnaces.

(*c*) Some work has been done on the reliability of the platinum, platinum-rhodium thermocouple at low temperatures after it has been exposed to high temperatures.

(*d*) *A new potentiometric millivoltmeter.*—A member of this division, in cooperation with members of the electrical division, devised two simple methods of accurately measuring the electromotive force of thermocouples, the methods requiring only cheap low-resistance millivoltmeters.

(*e*) *Homogeneity test.*—A simple method has been developed for use in the high temperature laboratory to test the homogeneity of thermocouple wire. The method greatly magnifies the effect due to the presence of local impurities.

(*f*) *Thermoelectric inhomogeneity.*—It was observed that if a platinum wire is heated so that it has a sharp temperature gradient, and if the gradient is varied unsymmetrically, a thermal electromotive force is developed, even for a wire which is usually considered homogeneous. A similar effect has been observed heretofore for iron and the explanation given by Trouton (Proc. Roy. Soc., Dublin, vol. 5, p. 171, 1886–87) for iron does not seem to apply for platinum—i. e., that heating alters the structure of the metal and the alteration lags behind the change in temperature. However, further experiments are in progress.

(*g*) *A simple modification of the Wanner pyrometer.*—By pivoting one section of this pyrometer, it was easily converted into a useful laboratory instrument forming either an ordinary König-Martens spectrophotometer or a spectral pyrometer.

(*h*) *Critical points in base metal thermocouples.*—Temperature electromotive force curves of the iron-constantan thermocouple were taken at temperature intervals of a few degrees by means of a special set up, with a view to detecting the presence of critical points or regions and determining their effect on the calibration.

The work briefly summarized under paragraphs (*a*) to (*h*), much of which is nearly completed, will be prepared for publication as time permits.

Methods of Testing Refractory Materials.

The Bureau is cooperating with the American Society for Testing Materials in a study of the methods of testing materials used to withstand high temperatures. Methods of determining the following properties are being studied: Melting point, chemical composition, thermal conductivity, thermal expansion, porosity, permanent volume change, crushing strength at ordinary and at high temperatures, resistance to abrasion, resistance to spalling, resistance to slagging action.

Any experimental work that may be required will be done in one or the other of the laboratories of the Bureau equipped for the work in question.

The Marvin Pyroheliometer.

Considerable work was done during the year on the primary calibration of a Marvin pyroheliometer, a type of instrument used by the United States Weather Bureau for the measurement of solar radiation. This is probably the first time that a pyroheliometer has been standardized by allowing a known amount of radiation to fall upon the receiver. Various possible sources of error were considered. A paper describing this work is in preparation.

The Fire and Explosion Hazard in Filtering Gasoline.

The Bureau of Standards has recently received many inquiries regarding the danger accompanying the filtering of gasoline, resulting from the production of static charges of electricity, which may produce sparks of sufficient intensity to ignite a mixture of gasoline vapor and air. The Bureau is engaged in an investigation of the conditions under which such electric charges may be produced. When this work is completed the results will be published in a technologic paper.

It is found that charges of considerable magnitude may be produced when the gasoline is filtered through chamois skin, and also through other insulating filtering mediums. Greater charges are produced when the air is cold and dry than when it is warm and damp. When the air is dry and cold it is extremely difficult to avoid the production of static charges of electricity when the gasoline is filtered through chamois skin. The amount of static electric charge produced is so much less when the gasoline is filtered through fine wire gauze that the hazard is practically eliminated.

When insulated from the ground and the tank, the funnel receives an electric charge of one sign, while the gasoline running into the tank carries an electric charge of the opposite sign. If then the funnel is brought near the metal of the tank, a spark passes between

the funnel and the tank, and if the mixture of gasoline vapor and air at this point is an explosive one, an explosion may result.

In addition to the electric charge produced by filtering the gasoline, charges may be produced by the friction of clothing against the cushions of automobile seats, by gloves against other materials, etc.

The danger due to the production of charges in both of these ways may be avoided by touching the funnel against the metal tank at some distance away from the opening before inserting the funnel into the tank, and then inserting it into the opening in the tank in such a way that it remains in metallic contact with the tank until the filtering is completed. The funnel should not be lifted out of contact with the tank while the filtering is in progress. These two precautions prevent the accumulation of charges of opposite sign on the funnel and the tank, respectively, and thus eliminate the possibility of the passage of an electric spark between the two.

Several accounts of explosions due to the passage of electric sparks produced in the ways above discussed have recently been reported in the newspapers. The cause for this hazard has only recently been recognized, and it is no doubt true that a number of explosions attributed to unknown causes have been due to this cause.

The reason that such explosions are not more frequent is that the conditions are seldom just right to cause an explosion, due to the fact that the gasoline vapor and air mixture at the point of passage of the spark is not of exactly the right proportion to produce an explosive mixture, such mixtures not being explosive unless the components are present in certain proportions. If the mixture contains too little or too much gasoline vapor it is not explosive.

Liquid-Air Plant.

The liquid-air plant has supplied liquid air to the several divisions of the Bureau as it has been required by the researches and tests in progress. On a number of occasions liquid air has been furnished to university and research laboratories, Government bureaus, and for lectures before teachers' organizations.

One of the new liquefiers, using liquid carbon dioxide precooling, showed in a preliminary test a capacity of about 10 liters of liquid air per hour.

The carbon dioxide compressor has been run almost daily throughout the year to operate low-temperature baths required by the investigation of refrigeration constants and by the thermometer laboratories.

Oxygen has been supplied to the chemical laboratories throughout the year from the electrolytic oxygen and hydrogen gas generator installed during the previous year. This equipment has been further supplemented during the year by the installation of two 50-cubic-foot gas tanks and the completion of a special gas compressor, described below, which will enable this plant to supply hydrogen as well as oxygen to the several laboratories of the Bureau, either in pipe lines or compressed to high pressures in steel cylinders.

A Compressor for Pure Gases.

A new gas compressor for the compression of pure gases has been completed during the year. This compressor is so designed that the gases are compressed in steel cylinders above mercury pistons without

the possibility of contamination by other foreign substances. Pressures up to 100 atmospheres are attainable and the capacity for continuous running can be varied from 15 liters per minute to 1.5 liters per minute measured at atmospheric pressure.

The Laws of Plastic Flow.

Plastic flow has been taking a position of increasing prominence in various lines of work, in geophysics, colloidal chemistry, metallurgy, ceramics, road building, and the lime, paint, and cement business. The problem frequently arises how to prepare two substances of similar plastic behavior, and there has long existed a need for some direct measure of the properties upon which plasticity depends. Naturally the solution of both of these problems depends upon the discovery of the laws of plastic flow, which have received practically no attention up to the present. In fact, plastic flow is often confused with viscous flow and naturally with disappointing results since the two types of flow differ fundamentally. In view of these facts an investigation of the laws of plastic flow was begun, and the results have already been published in Bulletin Volume XII, pages 309–354, 1916. It is shown that a plastic substance differs from a viscous substance in that with the former a definite shearing stress is required before a continuous deformation will be produced. This "internal friction" is a characteristic constant of the plastic substance. Furthermore, the rate of flow of a plastic material enables one to calculate another characteristic constant known as the "mobility." Incidentally this investigation gives an instrument by means of which these plasticity constants may be determined for a given material.

Viscosity Measurements.

The Bureau receives frequent requests for liquids of high viscosity whose values are accurately known. To meet this demand, the viscosities of aqueous sugar solutions have been carefully determined over a wide range of temperatures. The results, to which all of the known corrections have been applied, are expressed in absolute units.

Summarizing and recomputing the best determinations of the viscosity of water at 20°, the most probable value is found to be 0.010050. It is suggested that certain advantages would result if this value were uniformly used in calibrating instruments. Since this value is very nearly 0.01, it is proposed that the one-hundredth part of the absolute unit of viscosity (the poise) be called the centipoise, and that viscosities be expressed in terms of this unit. The most obvious advantages of this proposal are in having the most used viscosities expressed in whole numbers and in having viscosities expressed practically in terms of the viscosity of water at 20° C.

The paper describing the above work will be prepared for publication early in the fiscal year 1916–17.

Work in Connection with the International Ice Patrol.

In the past three years the Bureau has been represented on the cruises of the U. S. cruisers *Chester* and *Birmingham* and the U. S. Coast Guard cutter *Seneca* in connection with the international ice patrol of the steamer lanes of the North Atlantic Ocean. In the first cruises, methods of obtaining continuous records of sea-water

temperatures were tried out with a view to testing the usefulness of such records for predicting the proximity of icebergs. Thoroughly satisfactory methods of obtaining continuous temperature records were developed, but it was found that such temperature records were no guide to determining the proximity of icebergs owing to the large and erratic fluctuations of temperature of the sea water in some parts of the ocean. In the later cruises the temperature recorders were applied to a rather detailed study of the temperatures of the currents off the Banks of Newfoundland and vicinity. This work was supplemented by determinations of the densities of the sea water by a method developed by the Bureau with a special view to its applicability aboard ship, together with current measurements on the tail of the Great Bank, and some further observations on the temperature variations of sea water in the immediate vicinity of icebergs. Some work was also done on atmospheric nucleation with respect to the formation of fog, including measurements of corona and of total liquid contents of fogs. On one of these cruises the Bureau observer also took meteorological observations for the Weather Bureau.

It is believed that these annual cruises afford an excellent opportunity for continuous and systematic oceanographic observations, but such work does not properly come within the scope of the Bureau's activities. There are no oceanographers on our scientific staff. If this work is to result in the accumulation of systematic scientific data it should be placed in charge of a committee of men especially interested in oceanographic work intrusted with the power to plan a systematic and continuous program of work, and sufficiently interested in the work to review it and revise it from time to time. As will be observed from the summary above given, the Bureau's activities in this field have been confined to developing instruments and methods that might be of use in oceanographic studies, such as methods of obtaining temperature records, of measuring fog densities, sea-water densities, etc. The Bureau would be pleased to offer its cooperation along these lines to any committee undertaking the supervision of this work, but it does not feel that it should be called upon to assume responsibility for work almost entirely foreign to its activities.

Activities in Technical Societies, Etc.

Members of this division cooperated with the committees on the sampling and analysis of coal and on refractory materials of the American Society for Testing Materials, and with the committee on aeronautics of the American Society of Automobile Engineers; presented papers before the American Society for Refrigerating Engineers on the work being done by the Bureau on refrigeration constants, and before the National Association of Steam and Hot Water Fitters on the work of the Bureau on thermal conductivity and heat transmission. The results of some of the investigations completed in the high temperature laboratories were communicated to the American Physical Society.

A member of the division visited Dover to witness a test of a new automatic chemical sprinkler. A conference was held at Pittsburgh with representatives of the Underwriters' Laboratories and the New England Mutual Laboratories to consider details of the fire tests on building columns, referred to elsewhere in this report.

Apparatus and Equipment.

Among the important new items of equipment installed during the year may be mentioned a Leeds and Northrup 12-point multiple thermocouple recorder, a Dinsmore platinum lined bomb calorimeter, a Wenner potentiometer, two 50-cubic-foot gas holders, two Leeds and Northrup resistance thermometer bridges, a large amount of special apparatus and machinery required for the investigations on the fire-resistance properties of structural materials, a special gas compressor referred to previously in this report, two high sensibility D'Arsonval galvanometers, a new conductimeter, a new and improved aneroid calorimeter, and considerable apparatus constructed in the instrument shops of the Bureau for the investigations on refrigeration constants.

New apparatus and equipment that should be provided as soon as opportunity affords are electric furnaces, heavy current transformers and rheostats, standard platinum thermocouples, refractory porcelain for high temperature work, and a number of standard thermometers.

Refrigeration Constants.

This very extensive investigation, undertaken at the request of American refrigeration engineers, expressed through their national associations, includes the determination of the fundamental constants of refrigeration engineering.

The work is being carried out with the cooperation of committees of the American Association of Refrigeration and the American Society of Refrigerating Engineers, the members of which visit the Bureau annually, keep in close touch with the work, and have rendered valuable assistance by practical suggestions. The program is as follows:

(*a*) The latent heat of fusion of ice.

(*b*) The specific heat of ice, —50° to the melting point.

(*c*) The specific and the latent heats of common refrigerants, such as ammonia, aqueous ammonia solutions, carbon dioxide, and ethyl chloride.

(*d*) The specific heats of the vapors of the common refrigerants.

(*e*) The densities or specific volumes of the saturated vapors and of the liquids commonly used as refrigerants.

(*f*) The vapor pressure-temperature relations of the substances commonly used as refrigerants.

(*g*) The density-concentration relation for aqueous ammonia solutions.

(*h*) The vapor pressure-concentration relation for aqueous ammonia solutions.

(*i*) The specific heats of brines.

(*j*) The density-concentration temperature relations of brines.

(*k*) The thermal conductivities of insulating materials used in cold-storage construction.

(*l*) Certain works problems, the solution of which seem to require the facilities of this Bureau.

The measurements (*a*) and (*b*) were completed before the current year and have been fully reported upon. The work during the past year consisted chiefly in carrying on the measurements upon ammonia. The laboratory work in determining the latent heat and the

specific heat of anhydrous ammonia was practically completed, and the results are being worked into form for publication. The specific volume in the liquid phase was measured and a preliminary report presented to the American Society of Refrigerating Engineers at their annual meeting. The determination of the specific volume in the vapor phase is in progress, but will probably not be completed for nearly a year. The measurements upon aqua ammonia were also commenced.

The investigation relative to thermal conductivities of insulating materials made considerable progress and is the subject of a special paragraph elsewhere in this report. A paper upon this subject was communicated to the American Society of Refrigerating Engineers at their annual meeting and will shortly appear in the journal of that society.

Among the works problems the investigation of noncondensable gas formation in ammonia systems was continued and is the subject of a paragraph in that section of this report which has to do with the chemical investigations. A specially designed and constructed ammonia-compression system is being assembled by the American Society of Refrigerating Engineers for use in this connection.

Thermal Conductivities of Insulation and Building Materials.

In addition to several commercial tests, investigational tests were made upon about 25 different kinds of materials, the samples being purchased by the Bureau in the open market. These include flax, asbestos, and cork products, and a wide variety of special materials. An investigation of the thermal conductivity of wood is in progress, several varieties having been measured.

The very great importance of confined air spaces in the construction of insulating walls led to an extended investigation of the laws governing heat transmission by confined air. Cells varying in thickness from 0.1 to 7 centimeters (about 3 inches) and in height from 20 to 60 centimeters (2 feet) were used, and from these results general conclusions were deduced which have a bearing upon spaces of sizes commonly employed in building construction. A special thermocouple system was designed and constructed for the measurement of temperature gradients in very narrow air layers under a variety of conditions. The investigation is being continued. Experiments were also made with other common gases, carbon dioxide, and hydrogen, also air saturated with water vapor.

An important factor in the transmission of heat through layers of air is the radiation between the bounding walls, which depends on the character of the surfaces. A special series of experiments with three types of surfaces—lampblack, copper, and polished nickel—gave important data.

Some progress has been made on the construction of the elaborate equipment required for the determination of thermal conductivities of building materials. This apparatus is being adapted for work up to 800° C. (1,500° F.). All of this apparatus is necessarily specially designed for this work and must be constructed in the instrument shops of the Bureau.

The Fire-Resisting Properties of Structural Materials.

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

Fire Tests of Building Columns.

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

The fire tests on building columns are being carried out jointly by the Underwriters' Laboratories of Chicago, the Mutual Laboratories of Boston, and the Bureau of Standards. The first series of tests was originally planned to include about 70 structural steel columns and about 6 reinforced concrete columns. During the past year, while the steel columns were being fabricated and assembled and the various aggregates and covering materials were being brought together from different parts of the country, a detailed syllabus of the proposed tests was prepared and sent to several hundred engineers and architects interested in fireproof building construction as well as to various technical societies with a request for criticisms and suggested modifications of the proposed program of tests. At a conference of the several laboratories jointly conducting these tests held at Pittsburgh in March, 1916, the many valuable suggestions and criticisms called forth by the publication of the syllabus of tests were carefully considered, and the program of tests was finally revised. While the original program was modified in many minor but important details in accordance with the suggestions that had been received, the most important modification consisted in the addition of about 20 additional fireproofed structural steel columns, which will be subjected to the combined action of fire and water, the water being applied after a one-hour exposure to fire.

The specially designed furnace, which is being erected by the engineers of the Underwriters' Laboratories especially for these tests, together with the 200-ton hydraulic jack for applying loads of 50 tons to the columns while exposed to fire, the trolley cranes for moving the walls of the furnace to permit of the application of water, etc., have been installed, with the exception of the burner for heating the furnace by means of natural gas. The steel columns, representative of the types commonly employed in building construction, are now being covered with concrete, plaster on metal lath, clay tile, and gypsum tile coverings. Thermocouples are being built into the

column coverings to enable the temperature changes of the structural steel to be followed throughout the course of the fire test. Some of the important parts of the specially designed deformeter for measuring the amount of deformation produced in the column during the test have been completed. It is planned to begin the fire tests early in the coming winter. It is confidently believed that the results of these tests will be a most important contribution to modern structural engineering.

Thermal Efficiencies of Column Coverings.

Tests have been under way during the past two years at the Pittsburgh branch laboratories of the Bureau on the rate of temperature rise within cylindrical specimens of the various materials used for fireproofing building columns. A special gas heating furnace was built for this work, and a large number of cylinders of different materials were tested with thermocouples mounted axially in the cylinder and with their junctions at different distances from the surface. Cylinders, similar to the cylinder under test, were placed at each end of the latter, in contact with its end faces, to minimize the disturbing effects of heat losses from the ends. This investigation is practically completed with the exception of a few tests to round out the series. It will be prepared for publication as soon as time will permit.

Strength of Steel at High Temperatures.

Some tests on the compressive strength of steel at high temperatures, briefly reported in the last annual report, showed that at 600° C. the compressive strength had decreased to 60 per cent, and in the next 50° C. (i. e., at 650° C.) to about 30 per cent of its value when cold. Such data are of fundamental importance in their bearing on the behavior of structural steel when exposed to fire conditions. One of the items which it was hoped to provide for with the increase in the fire-resistance appropriation, asked for last year but not granted, was a thorough investigation of the elastic properties of steels throughout a wide range of temperature. All the elaborate equipment required by such an investigation is available, so that it could be completed with an annual expenditure of about $4,000 during the next two or three years.

Panel-Testing Furnace.

The panel-testing equipment was installed during the year. It consists of a large oil-heated furnace, with necessary accessories such as steam boiler, 2,000-cubic-foot motor-driven blower, 1,000 gallon oil tank, motor-driven fire pump, five massive structural steel frames into which the test panels or partitions are built, a massive structural steel panel rack for storing 12 panel frames, trolleys and cranes for moving the panel frames from the storage rack to position before the furnace, and structural steel housing over the entire plant, together with storage bins for the materials to be used in building up the test panels. The cost of the equipment thus far installed is about $15,000. The seven additional panel frames required to complete the plant should be provided as soon as the necessary funds are available. At the present high prices for structural steel these would cost about $5,000. The plant has been operated several times to test its performance and has been found admirably suited to the work for which it was designed.

These panel tests are necessarily expensive, requiring as they do the test to destruction of large structural units. The average cost of a panel test is about $200. The equipment that is now available for this work is probably the most complete that has ever been built, and its efficient utilization should include as a minimum 30 panel tests a year. The completion of this plant and its efficient utilization was one of the items which it was hoped to provide for by the increase in the fire-resistance appropriation asked for last year. The work of testing the fire-resisting properties of building partitions and walls will necessarily have to be carried on quite inefficiently, being confined to a few tests a year, unless provision is made for it by an increase in appropriation.

Steps have been taken to secure the cooperation of prominent engineers, representatives of engineering and technical societies, and of manufacturing associations, in the formulation of a comprehensive program of tests of the fire-resisting properties of structural materials.

Thermal Conductivity and Thermal Expansion of Structural Materials.

As stated elsewhere in this report, progress has been made in the construction of the large amount of special apparatus required for these investigations and on the development of the methods that may be used at high temperatures.

Building Codes, Information, Cooperative Work, etc.

The engineering data resulting from investigations such as those above referred to must serve as the foundation upon which building codes must be constructed. Some progress has been made during the year in compiling the municipal building codes, not alone with a view to furnishing information to State and city building bureaus and to others interested along these lines, but with a view to a comparative study of existing codes to assist in planning a systematic program of investigations to definitely answer the many important questions about which there are still great differences of opinion.

Progress in summarizing the enormous amount of material contained in the many municipal building codes is necessarily slow with the present wholly inadequate force that can be assigned to this work; indeed, it is an endless job. Several capable assistants with a good engineering training and experience, and as many clerks, should be kept on this phase of the work uninterruptedly if reasonable progress is to be made. At the present time as each city takes up the question of revision of its building code it expends large sums of money and much time in making a very imperfect summary of a few existing codes—just sufficient to imperfectly serve its immediate needs—with the result that large sums of money have been expended in the past for such work, the results of which are available to nobody. It is evident that this work should be well done once, and thus made generally available. In addition to summarizing American building practice as exemplified in our building codes, the building practice of the most important European cities should be collected and made available to our State and municipal building bureaus when they take up the revision of their own codes.

Most of the available building codes of the 100 largest American cities have been collected during the year, as well as the recent reports of the State fire marshals. Considerable correspondence has been carried on with engineers and officials interested in fire-prevention work, and the Bureau has cooperated with committees of the National Fire Protective Association in their several lines of work and with committees engaged in the preparation of State building codes. Some work has also been done in the collection of data on the common causes of fires and on material for a circular relating to safety in the household.

Numerous public organizations are cooperating in a nation-wide movement to decrease the enormous annual fire waste in life and property. It is the duty of the National Government to lend efficient cooperation in this laudable and unselfish public service. At the present time the Bureau can do but little along these lines for lack of funds and personnel.

Recommendations Concerning Fire-Resistance Investigations.

With an annual life and property loss conservatively estimated as some thousands of lives and exceeding $300,000,000, a per capita loss nearly 10 times as great as that found in the leading European countries, and this in spite of the most expensive and efficient fire-fighting equipment in the world, it would be a neglect of duty not to direct attention to the pressing needs for greater activities on the part of the National Government in the nation-wide movements to diminish this unpardonable waste of our national resources. The National Fire Protective Association, through its 125 or more allied engineering, industrial, commercial, municipal, and State associations, has done and is now doing splendid and unselfish work in this great public movement. It is the moral duty of the National Government to lend its fullest cooperation and assistance to this great work. Briefly summarized below is the work that the Bureau should undertake, with the increased appropriations requested for investigations of the fire-resisting properties of structural materials. There is an urgent public demand on the Bureau for this work, and the testimony of many of the most eminent American engineers can be given in support of it.

The field of activity in which the Bureau can be of the greatest service to the many organizations now enlisted in the fight against our enormous fire waste is in the determination of fundamental engineering data to serve as a basis for the revision and reconstruction of State and municipal building codes. The important investigations now under way that are expected to yield data of direct practical application are the fire tests of structural steel building columns, fireproofed in different ways, and of reinforced concrete columns of different aggregates and types of construction. A small increase in appropriation is required to carry on these investigations. To make any reasonable progress in the work of summarizing the vast storehouse of data contained in existing building codes, an increase of at least $10,000 will be required. The large panel furnace, owing to the increased cost of materials, will require about $5,000 for its completion and at least as much more for its efficient operation, for reasons previously set forth. The important investigation relat-

ing to the elastic properties of steel at high temperatures, work on which has only been possible at intervals, should be taken up in earnest and pushed to a satisfactory conclusion. This investigation could be carried along with an expenditure of about $4,000 a year.

The above recommendations relate to work well under way. It is imperative that several new lines of work be started at once. Building columns, walls, and partitions, which will be quite well taken care of by the above program, are only a few of the structural parts that must be considered in building codes. Tests of floors, roofs, fire-resisting doors, shutters, windows, etc., most be included in this program, and must be carried along with the column and partition tests, if we are to be in a position at the end of a few years to lay before American engineers a comprehensive set of data to enable them to redraft our present unsatisfactory codes in the light of the best modern engineering experience. If we do this work in series, i. e., wait until the column tests are completed before taking up floor tests, etc., instead of in parallel, it will be a generation before a complete entity of results will be made available to structural engineers, and the work that was done in the beginning of the program will be, if not semiobsolete, at least out of phase with existing building practice.

To provide for these additional lines of work, considerable expensive equipment will be required. A complete floor-testing equipment will cost about $20,000. The equipments for testing roofs, fire doors, shutters, and windows will cost about $15,000. In asking for the increased appropriations, it has been planned to install parts of these equipments yearly during the next three years, by which time all of these lines of work should be well under way. Another equipment which should be immediately provided, even before the above-mentioned items, is a fire hut about 50 by 25 feet, one story high, for special experiments on the standardization of fire tests. Most valuable information could be obtained by observing the temperatures obtained in characteristic types of fires in such a test structure, e. g., when furnished as an office, as a furniture storage warehouse, as different units of a department store, etc. Information obtained in this way, supplemented by data collected in field inspections after large fires, would serve as a valuable guide in preparing specifications that materials entering into different types of building construction must withstand as to their fire-resisting properties in order to satisfactorily meet service requirements. Such a test structure could be built and equipped for about seven or eight thousand dollars, and all the required tests could be completed for an additional $10,000.

Testing of Heat and Thermometric Apparatus.

During the year 1,329 mercurial thermometers of various kinds were submitted for test, of which 1,259 were certified. Among those submitted there were 125 ordinary calorimetric thermometers, 131 precision calorimetric and Beckmann thermometers, 11 clinical standards, and the remainder laboratory and special thermometers of various types and ranges from below 0° to 500° C. About 0.8 per cent were received broken and about 2.1 per cent were broken in the process of testing.

Twelve thousand and seventy-nine clinical thermometers were submitted for test; of these 11,209, or 92.8 per cent, were certified. The percentage of those rejected amounted to 7.2 per cent of the total number submitted; 0.9 per cent were rejected on account of defects of construction, 0.3 per cent because of too great difficulty in throwing back index, 0.6 per cent on account of retreating of index, 0.6 per cent were received broken, 0.3 per cent were broken in testing, and 4.5 per cent exceeded the limits of allowable errors.

In addition to the above, there were tested in the thermometer laboratories 8 platinum resistance thermometers and 16 thermocouples; the freezing points of 12 samples of fire-extinguishing liquids, several glycerin and 2 brine solutions; test of effect of low temperatures on insulation of wire; tests of a viscosimeter and a flash-point apparatus.

Among the calorimetric tests were 18 gas calorimeters and determinations of the water equivalents of 2 bomb calorimeters. Two hundred and fifty-seven standard heat samples were furnished during the year.

In the high-temperature laboratories there were tested 2 radiation pyrometers, 8 optical pyrometers, 1 absorption glass for extending the range of an optical pyrometer to very high temperatures, 2 melting-point determinations of wire samples of gold and platinum, 19 base metal thermocouples, with accompanying pyrometer galvanometers, 140 special base metal thermocouples intended for the fire tests on building columns, 12 rare metal thermocouples, with accompanying pyrometer galvonometers, 36 rare metal thermocouples, 8 tests for thermoelectric homogeneity, 3 annealing tests to restore used couples, life test of a base metal thermocouple, melting-point determinations of 1 sample foundry clay, of 1 sample of material for electric resistors, of fire brick, of 4 samples of high-temperature cements, and of 1 mineral.

Besides the above tests may be mentioned tests made on the heat loss through the different sides of a model beehive for one of the bureaus of the Department of Agriculture; the necessary apparatus was loaned and installed for measuring the temperatures in the interior of cotton bales, in connection with some experiments being conducted by one of the bureaus of that department; facilities were extended to an investigator for testing a new color pyrometer; witnessing test of a new automatic fire extinguisher; test of the fire hazard of a moving-picture machine using acetate of-cellulose films, with a view to use on passenger steamers, etc.

Almost every variety of the manufacturing industries is represented in the above summary of tests, as well as Government, State, and municipal bureaus, technical schools, universities, etc. Of the total work of testing done by the heat division, somewhat less than half is done for the various bureaus of the Government, the remainder for the general public.

Information Furnished, Reports, etc.

Several hundred special letters and reports relating to the work of this division were prepared during the year in reply to inquiries addressed to the Bureau by engineers and technical men, scientific

investigators, National, State, and municipal bureaus and laboratories, etc. The subjects treated are illustrated below.

High temperatures.—Pyrometer installations for ceramic, cement, and brick kilns, for gas manufacturing plants, for various metallurgical operations, and for chemical manufacturing plants; seger cones, pyrometer testing, thermocouples, base and rare metals and their protection under different conditions of use, optical and radiation pyrometers, molding material for very high temperatures, elastic properties of steel at high temperatures, temperatures of various industrial operations, electrical resistivities at high temperatures, resistance thermometers, construction of mirror for radiation pyrometer, etc.

Melting points of metals, salts, oxides, the elements, refractories, cements, fire brick, etc.

Thermometry.—The stem correction for thermometers, temperature baths for testing thermometers, the manufacture and testing of clinical thermometers, setting corrections for Beckmann thermometers, thermostats, use of nickel for resistance thermometers, construction of platinum resistance thermometers, thermometers for measuring lowering of freezing points of solutions, specifications for various types of thermometers, thermocouples for low temperatures (—200° C.), recording thermometers, effect of time changes in thermometers, etc.

Calorimetry.—Calorimetric resistance thermometers, resistance versus mercurial thermometers, calorimeters for fuel testing, heats of combustion, etc.

Specific heats of water from 200° to 400° F., of methane, of gases at high temperatures, of metals, of petroleums and their distillates, etc.

Thermal conductivities of metals, wood, concrete, salts, fire bricks, cotton and wool, insulite, fibrofelt, flaxlinum, cork, and other insulating materials used in cold storage and refrigerator construction; the testing and construction of refrigerators; apparatus for determining thermal conductivities; insulating materials for use at high temperatures; the heat transmission and surface temperatures of boiler tubes and of the fire-box sheets of locomotive boilers; etc.

Oils, etc.—Specifications, instruments used for viscosity and flash-point tests, distillation oil tests at low barometric pressures, air-kerosene mixtures in oil engines, specific heats, heats of combustion, so-called substitutes for gasoline, etc.

Miscellaneous topics.—The production of liquid air, liquid oxygen, and carbon dioxide; separation of O and N of the air; the mechanical equivalent of heat; use of the term "therm"; the critical temperature and pressure of water; effect of dissolved air on freezing point of water; a thermostat to deliver water at constant temperature; freezing of sprinklers; measurement of surface temperatures of moving picture machines; internal-combustion engines; tungsten spark gap terminals; etc.

A large number of technical men have visited the laboratories to study the methods in use and to consult with the men engaged in the several lines of work on questions relating to pyrometric methods and equipment best suited to particular works problems; the determination of melting points, thermal conductivities, heating values,

etc. A member of the faculty of one of our western universities spent a week in the high-temperature laboratories studying the methods and instruments in use there with a view to introducing such work into the laboratory courses in the university.

3. ELECTRICITY.

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

Weston Standard Cell.

Considerable further work has been done on the Weston normal cell, the primary standard of electromotive force, in an effort to increase both the accuracy with which it may be reproduced and its constancy with time. Since the chief source of variation in the cell is the mercurous sulphate, and since the washing of this material when made by alternating-current electrolysis has been found to underlie the variations, most of the time has been spent in perfecting the method of washing. In washing it has been customary to employ alcohol and ether to free the mercurous sulphate from all traces of the sulphuric-acid solution in which it is formed. Cells recently set up show that the ether must be redistilled immediately before use. There are also indications that in washing the mercurous sulphate the alcohol and ether may be replaced by acetone. Further work is now being done along these lines, and it is hoped that in the near future the Bureau may be in a position to lay down definite specifications for the preparation and purification of all the standard cell materials, so that anyone, when taking the proper precautions, may reproduce the primary standard of electromotive force to an accuracy of at least a few parts in 100,000.

Volume Effect in the Silver Voltameter.

The international ampere is defined in terms of the rate of deposit of silver by an electric current in the silver voltameter. One of the series of investigations upon this instrument which has just been completed is a study of the so-called volume effect.

The volume effect is a phenomenon occurring when the electrolyte is not sufficiently pure and consists of an excess of deposit in the large size of voltameters over that deposited in the small voltameters by the same electric current. It is a useful criterion of the purity of the electrolyte. The new experiments and a recalculation of former experiments bearing on this subject show conclusively that the volume effect is due to the impurities of the electrolyte and that it is essentially the same in all the forms of silver voltameter used for precision work, all of which forms have been investigated at the Bureau. These results are published as Scientific Paper No. 283.

Inclusions in the Silver Deposits.

Another investigation recently completed is a study of the inclusions in the voltameter deposits. By inclusions is meant the minute quantity of foreign matter (chiefly water in the case of pure solutions) which is deposited with the silver as an impurity. Since the

amount of silver deposited is a measure of the quantity of electricity passed through the voltameter, it is important to determine the magnitude of the small correction necessary to apply to the weight of the deposit due to the inclusions. This investigation has been completed and published as Scientific Paper No. 271. During the course of this work it was found that previous observers had overlooked an important source of error, and hence in some cases had found much too large values for the inclusions. The average value of the inclusions in the best silver deposits was found to be 0.0040 of 1 per cent. The final value for the absolute electrochemical equivalent of silver is 0.00111800 gram per coulomb, in terms of the voltameters and the current balance of this Bureau. The absolute value computed for the faraday, which is an important constant of electrochemistry, is 96,494 coulombs.

Specifications for the Silver Voltameter.

To conclude the series of papers on the voltameter (eight in number) a résumé of the investigations at the Bureau has been prepared, in order that the essential facts of this research extending through a period of about eight years may be made available in condensed form. The Bureau's proposals for the international specifications for the voltameter have been included in the paper. It is anticipated that when it shall be possible to again consider the question of an international specification with the representatives of other countries, these specifications will be an important contribution to the material available for discussion. This final paper on the silver voltameter is now in press. An appendix to it contains an exhaustive bibliography of the subject.

Circular on Electric Units and Standards.

The available information on the fundamental electric and magnetic units has hitherto been scattered over an extensive literature. A circular has therefore been prepared (Circular No. 60), giving a comprehensive and up-to-date treatment of the various units and the standards by means of which the units are maintained. This compendium will be of use to teachers and students, to testing laboratories, and to electrical engineers. It takes the place of certain previous publications of the Bureau dealing with special aspects of the subject, and includes a history of the units and the evolution of the definitions upon which the laws on electrical standards are based. The present status of the fundamental electrical standards is described, and the laws on electric units in the various countries of the world are given. The laws of the different countries are now in substantial agreement, and the various national institutions cooperate in maintaining the fundamental standards. The circular gives conversion factors, by means of which measurements may be expressed in any desired unit, and also gives a selected bibliography of previous writings on electric and magnetic units and standards. In connection with the preparation of this circular, a critical study was made of the various systems of units which have been proposed from time to time as having noteworthy advantages over the commonly used system. These diverse units are used to some extent at the present time and are a source of confusion to the student and the engineer.

As a result of comparing all of these systems, it appears doubtful whether any of the proposed systems of electrical units is materially superior even in its theoretical aspects to the international system of units in general use.

Galvanometers.

Sensitive galvanometers are used in various kinds of electrical measurements in which the accuracy or precision must be high, as, for example, the comparison of resistance standards, the use of potentiometers, and the measurement of temperature very accurately by resistance thermometers. An investigation of galvanometers has been in progress for some time. One of the aspects of the work is the study of the general design of galvanometers. A discussion of this has been published as Scientific Paper No. 273. The paper gives the mathematical relations between the operating constants of a galvanometer and the factors entering into its construction, such as the magnetic field and the shape, size, and kind of material of its parts. Procedures are outlined for the construction of galvanometers for various particular uses.

Galvanometer Shunts.

In the use of galvanometers it is often necessary to use a shunt or some other means for reducing the sensitivity, otherwise the deflection would sometimes be excessively great. In case the galvanometer is used to measure current or current impulse, the Ayrton or universal shunt, which has long been in use, is entirely satisfactory. However, this shunt can not be used when the quantity to be measured is either a voltage or voltage impulse. Shunts are made for this particular use, but they are rather complicated and have not come into general use. The matter has been investigated at the Bureau and much simpler shunts have been devised for reducing the sensitivity (either to voltage or voltage impulse) by any desired factor without changing the damping.

Bridge for Testing Precision Resistance Standards.

A resistance measuring bridge, designed especially to meet the Bureau's needs in the accurate comparison and testing of precision resistance standards, has been under construction in the instrument shop and laboratory. When it is completed and thoroughly tried out, it is planned to publish a description of it and other apparatus and methods used in the testing of precision resistance standards.

Standard Electric Condensers.

Tests have been made upon the recently constructed air condensers of fixed value using quartz insulation. Changes in the capacity were at first observed, but after thoroughly annealing the brass plates the capacity remained very constant. However, on humid days sufficient moisture would be deposited on the plates to increase their thickness by a very slight amount, and, therefore, increase the capacity by an appreciable amount. Therefore, for very precise work, it is necessary to seal the condenser and keep a drying agent in the condenser case. These fixed-value air condensers have been so satisfactory that similarly designed variable air condensers have been constructed.

The results upon air condensers which have been sent to the Bureau for test show the difficulties which are encountered in the design of this class of apparatus. Owing to improper insulating material or its location in the field of electrostatic force, several of these were poorer standards than good paper condensers would be. The same difficulty is encountered in the mounting of other condensers. Some unmounted mica condensers having a capacity of a thousandth of a microfarad recently furnished to the Bureau showed a very satisfactory behavior. However, when these condensers were mounted so that the leads came through a hard-rubber top, their properties were decidedly different. Investigation showed that the trouble lay in the hard-rubber top. Any improvement must await the development of a satisfactory substitute for hard rubber which will have better dielectric properties.

Investigation of Inductance Coils.

A research has been in progress on the determination of resistance and inductance of coils at different frequencies, a subject which is of considerable importance to telephone engineers. As the frequency of the alternating current is increased, the resistance of the coil increases and the inductance decreases. At a frequency of 1,000 cycles per second the resistance of one henry coil may be several times the value which it has when measured at 100 cycles, while the change in inductance is never more than a few per cent. These changes are caused by skin effect in the conductor, eddy currents in neighboring masses of metal, capacity between the different turns, and dielectric loss in the surrounding insulators. By properly designing a coil, the effect of each of these can be greatly reduced. A paper on the subject is being prepared.

Testing of Electric Fans.

In connection with the annual competitive test of electric fans submitted by bidders to the General Supply Committee, further time and study have been given to the improvement of the apparatus and methods used in fan testing. The general problem is that of measuring the air delivered without the use of apparatus which would appreciably impede its flow. Further work is necessary before the method can be standardized and permanent apparatus constructed.

Projection Apparatus for Instrument Scales.

In testing electrical instruments in which a pointer moves over a scale, it is ordinarily necessary to observe the pointer very closely, often with the aid of a magnifier. To avoid eye fatigue and to increase the accuracy of the work, an optical projection apparatus has been designed and constructed, which throws a magnified image of the scale and pointer on a ground-glass screen.

Four-Terminal Resistance Standards.

A further study has been made of the inductances of resistance standards, particularly those intended for carrying very heavy currents. As a closely allied topic the phase relations of currents in mutual inductance standards have been studied. The results are embodied in Scientific Paper No. 281.

New Instruments.

A study of the literature of the electrostatic wattmeter was made, and a wattmeter was designed for the measurement of a few watts at several thousand volts and low-power factor. The apparatus, which was constructed for use in connection with a new process for the fixation of atmospheric nitrogen, was tested by the Bureau and found to give satisfactory results.

A new form of vibration galvanometer has been in course of development and gives promise of good sensitivity, simplicity of construction, and relative freedom from trouble caused by the vibration of the support on which it is placed. This instrument will facilitate such electrical measurements as the testing of transformers.

A new type of transfer instrument which permits the standardization of alternating-current instruments in terms of direct-current standards has been devised. A direct and an alternating current are passed through the same windings of an electrodynamometer in such a way as to oppose each other. The instrument is now under study to ascertain what advantages it may have over previous types of transfer instruments.

Standard Circuits for Radio Work.

The equipment of the radio laboratory has been extended and facilities provided to increase the range and efficiency of the testing and to take up several investigations. Standard circuits are now available for measurements of wave length up to 20,000 meters. The establishment of these circuits has involved the design and construction of inductance coils of minimum resistance and distributed capacity, and also the development of variable air condensers of minimum phase difference. It was found that by careful design, both in coils and in condensers, a considerable reduction of the energy absorbed in the insulating material could be effected and the usefulness of the apparatus thereby greatly increased.

Radio Service to Bureau of Navigation.

The laboratory has assisted the Bureau of Navigation of the Department of Commerce with technical information as heretofore. It has developed a lightweight portable decremeter and a combination instrument serving as a current-square meter, an ammeter, and a battery voltameter. This outfit reduces the entire testing equipment which the radio inspector must carry to a weight of 15 pounds. The ammeter in this outfit operates on the current transformer principle. The design is the result of experiments at the Bureau, which have been successful in developing a very compact and satisfactory instrument. A thorough test of a storage-battery equipment for emergency radio apparatus was made under operating conditions. A number of inductance coils were tested for the same Bureau.

Radio Equipment for the Bureau of Lighthouses.

The Bureau has been active in its efforts to promote safety at sea by means of radio instruments. A complete 1-kilowatt equipment for radio communication was designed and the construction supervised for installation at a newly established lighthouse. An equipment for a lighthouse tender was also designed and installed. These

sets are provided with special features adapted to the needs of the Lighthouse Service. The equipment of the lighthouses and tenders with radio apparatus is making it possible for them to render greater service to navigation than ever before. The fog-signaling apparatus was also completed. This equipment is designed to send out automatically a characteristic signal once every minute on a short wave length, so that it will be readily received by all ships within a few miles of the lighthouse. It will be particularly effective when the ships use direction finders to receive the signal, as they can then get their bearings by radio. The direction finder described below was developed for this purpose. The fog apparatus will be tried out as soon as possible at a lighthouse. It is anticipated that this will very efficiently supplement the light of a lighthouse during fog and be of great assistance to navigation.

Design of Radio Sets for Coast and Geodetic Survey.

A need has been felt for more ready means of communication in the coast work of the Coast and Geodetic Survey. This is being filled by radio equipment, two complete outfits having been designed here for the use of survey boats. These are 1-kilowatt sets and are specially adapted to the requirements of the Coast Survey.

Radio Direction Finder.

A simple type of direction finder has been developed and has been found very useful. This apparatus replaces the antenna for receiving radio communication, although it is so small in size that it can be used in an ordinary room. Signals from European stations have been received on it. It determines the direction of the sending station with high accuracy. Several models have been constructed for receiving both long and short waves. The apparatus was developed primarily for use on ships in the promotion of safety at sea.

Effect of Imperfect Dielectrics in the Field of a Radiotelegraphic Antenna.

A paper on the above subject has been published as Scientific Paper No. 269. It was found, by measurements both at radio and low frequencies, that a large part of the power loss in antennas is due to dielectric absorption in poor dielectrics, such as wooden masts, trees, buildings, and insulators with poor dielectric properties. Contrary to previous belief, it was found that the ground loss is a negligible part of the power loss in an antenna. The result of this investigation has an important bearing on the design and location of antennas.

New Work in Radio Communication.

A number of much-needed investigations have been either planned or already begun. The design of radio apparatus is at present limited by lack of precise data on high-frequency properties, such as the resistance of conductors of various forms. An investigation is in progress on the resistance of straight wires and strips and of coils of various shapes, wound with various kinds of wires, and mounted in several ways. Of like importance is new data on dielectric losses in the insulation used in radio condensers, coils, and instruments, and in the insulators used to support circuits and antennas.

An investigation of the various properties of insulators that are of importance in radio work is contemplated.

New data on the behavior of different types of antennas is urgently needed. At present the natural frequency, radiation resistance, and other characteristics of various types of antennas can not be determined with satisfactory accuracy. The methods of calculating and of measuring resistance, inductance, and capacity of antennas are to be studied. This will require laboratory investigation as well as experiments directly upon antennas. It will be necessary to construct small towers of various kinds upon which experimental antennas can be mounted.

Some additional investigation of the measurement of high-frequency currents is desirable. The ammeters upon which the measurement of the power radiated through space depends are seldom accurate. The proper design of such instruments and the thorough establishment of means for determining their accuracy are problems under study. There are other sources of error in many of the methods and instruments used in radio work which have never been thoroughly investigated. For example, the distributed capacity of coils and the stray capacities of circuits sometimes seriously affect the performance of a wavemeter or a sending or receiving set. This requires experimental investigation and study of the fundamental electrical theory.

One of the important unsolved problems of radio communication is directive sending and receiving. The elimination of interference by stations other than those desiring to communicate would be a great advance. Experiments on this are in progress at the Bureau. Radiotelephony is also assuming importance, and it is hoped to make some investigations upon this.

Use of Radiotelegraphy to Promote Safety at Sea.

The use of radiotelegraphy by the Government to promote safety at sea and to aid navigation has been by no means as thoroughly developed as it should be. This Bureau hopes to be of greater assistance to other civil branches of the Government in the future than it has been able to be heretofore, particularly such as are engaged in the protection of life and property at sea. Such assistance takes the form of information upon the design and use of radio instruments and equipments, the standardization of apparatus, and the adaptation of radio equipment to the particular needs of a given service.

New Radio Laboratory.

Radio communication has come to be of the greatest importance to a number of branches of the Federal Government as well as to the public. This method of communication is, however, still largely in the experimental stages. Future development and improvement depend greatly on the progress that is made in knowledge of the underlying principles and in the application of such knowledge to particular needs. The Bureau has done work of this character for several years, but is now planning to increase this work considerably, both by investigating fundamental problems and applying existing knowledge to the design and testing of apparatus.

The necessary expansion of this work has been made possible by an appropriation of $50,000 for a radio laboratory building. This building will accommodate the scientific investigations in connection with the radio work by the Bureau, and also that of the Army and Navy. This work has been carried on in a few rooms of the Bureau laboratories for several years. The close proximity of the radio building to the other scientific and instrumental resources of the Bureau will be a distinct advantage. The building will be two stories in height, and will be connected by means of a tunnel with the electrical laboratory, so that all the generators and other facilities of the Bureau will be directly available.

The construction and equipment of the new building and the transfer of the radio work to it will occupy considerable of the attention of the staff during the coming year. The additional space available will make it possible to take up and accomplish more than heretofore of the work which the rapidly increasing importance and range of radiotelegraphy demand. The additional equipment of apparatus and additional assistance necessary to make the new laboratory space effective can be obtained as soon as funds are made available. To this end, an increase in the funds available for radio apparatus and assistance is recommended for next year.

Uniformity of Magnetic Standard Bars.

Magnetic standard bars are used for the calibration of permeameters and the comparison of methods of magnetic testing with a standard method. One of the most important requirements of a magnetic standard bar is that it shall be magnetically uniform along its length. If this condition is not met, errors may arise which cannot be calculated or eliminated from the measurements, and which may be of considerable magnitude.

Considerable experimental work has been done in this connection, and a scientific paper has been prepared, which (1) describes a method for determining the degree of magnetic uniformity along the length of straight bars, (2) indicates the magnitude of the effect of non-uniformities on the accuracy of magnetic measurements, and (3) gives a criterion for the degree of uniformity of magnetic standard bars.

A large number of bars have been examined for magnetic uniformity, and it has been found that only a very few are satisfactory for use as standards. The bars which have been found to be satisfactory have been carefully standardized, and are used for calibration and comparison work.

Correlation of Magnetic and Mechanical Properties of Steel.

A paper bearing the above title has been published (Scientific Paper No. 272). It is a review of the work done in correlating the magnetic and mechanical properties of steel, with special reference to the commercial applications of magnetic data as criterions of the mechanical fitness of a given steel and of magnetic changes of steel under stress as indications of the state of strain. The evidence presented shows the interrelation of magnetic characteristics, and the mechanical behavior of steel is so close that the magnetic examination in conjunction with the mechanical tests may be expected to add consider-

ably to knowledge of the material. The magnetic method tests the whole amount of material and not merely some surface phenomenon. It leaves the test piece unaltered, so that it is possible to apply a magnetic test to the identical material that is to enter into a given structure.

Magnetic Analysis.

The work on the correlation of magnetic and mechanical properties has been continued with especial reference to the development of the details of the magnetic method of examination. The method has been applied successfully to the study of methods of heat treatment for spring steel, to the examination of hardened and tempered tools, and to the testing of wire mine and elevator cables for broken strands. A number of magnetic characteristics may be used as criterions for proper quenching. The simplest are the normal induction, the residual induction, or the evanescent induction corresponding to a given magnetizing force. Certain products and quotients involving these three quantities and the coercive force seem to be the best criterions of the proper hardness of finished knife blades and drills. A number of large manufacturers of steel products have indicated that they regard this work as of great importance.

Radium Testing.

Owing to a depressed condition of the radium market during 1915, the amount of radium the Bureau was called upon to measure during the first half of this fiscal year was small; sales increased markedly during the winter, with the result that the amount of radium measured for the public during the last half of the year was nearly twice as much as was measured during any previous corresponding period since the Bureau undertook this work. The total amount measured during the year was a little over 4.5 grams, which, at the current market price, is worth about $540,000. A number of large specimens were measured, one of which contained over eighteen times as much radium as the Bureau's largest standard. Such measurements would be greatly facilitated by the possession of larger standards.

Increase in the Bureau's Stock of Radium.

An increase in the Bureau's stock of radium is urgently needed. At present the primary radium standard of the United States is in daily use as a working standard. In view of the fragile nature of such standards, this is most undesirable, but can not be avoided until a working standard of about the same size is provided. Still another working standard, containing at least 50 milligrams of radium, should be available for use in the measurement of large specimens. The Bureau should acquire these two additional standards as soon as possible.

Radium Emanation.

The measurement of radium emanation is essential to the determination of very small amounts of radium (such as are contained in therapeutic preparations, ores, etc.), of the radioactivity in natural waters, and of the effective strengths of radium emanation activators; that is, apparatus for the artificial preparation of radio-

active water. Work of this kind has been carried out throughout the year. Several types of activators have been carefully studied, a number of them have been tested for the public, and numerous therapeutic preparations have been investigated. A number of radium solutions for the preparation of standards to be used in such work have been furnished to the public.

Luminous Preparation.

In response to urgent requests, the Bureau is about to undertake the testing of luminous preparations containing radium. These preparations are not only used for the illumination of watch and clock dials, but are most valuable in the construction of many military and naval appliances designed for use at night. The Bureau is informed that one company in this country is making regular monthly shipments abroad of large amounts of this material.

Circular on Radium.

Part of the work of the radium laboratory is to act as a clearing house of information, to encourage the adoption and use of the best units, nomenclature, and methods of measurement, and the elimination of all others; and to endeavor to secure honest advertisement of radium preparations. This work is carried on by correspondence, conferences, and publication. A circular, setting forth in a popular manner those facts concerning radium and radioactivity and their technical measurement which are of general interest or which should be clearly understood by all who desire to employ radioactive substances in any way, is nearing completion.

Life Testing of Incandescent Lamps.

The lamps purchased by the Federal Government, amounting to about 1,250,000 annually, are inspected and tested by the Bureau of Standards. The specifications under which these lamps are tested are published by the Bureau and are recognized as standard by the manufacturers as well as by the Government. They are used also by many other purchasers of lamps.

The lamps are first inspected for mechanical and physical defects, this being done at the factory by Bureau inspectors. Representative samples are selected and sent to the Bureau, where they are burned on life test at a specified efficiency, at which they must give a certain number of hours' life, depending upon the kind of lamp. From 3,000 to 5,000 lamps are thus burned on test each year.

For this test great care must be taken in the measurement of the lamps and in the adjustment and regulation of the life-test voltage.

Scientific Paper No. 265 gives a complete description of the special apparatus and of the methods used in these inspections and tests.

Photometry of the Gas-Filled Tungsten Lamp.

A study has been made of the measurement of candlepower of nitrogen-filled lamps. The usual method of measuring horizontal candlepower with the lamps rotating offers peculiar difficulties when applied to the gas-filled lamps. The candlepower is found to vary with the speed of rotation and the position of the lamp. This effect is caused by the variation of convection currents in the gas. Means

were found for overcoming the difficulties of measurement. A description of this work was published as Scientific Paper No. 264.

Improved Methods of Measurement in Photometry.

In order to establish satisfactory standards for measurement of modern lamps of high efficiency, particularly gas-filled tungsten lamps, which give a light much whiter than any of the other incandescent lamps and also give a much more irregular distribution of the light, methods of measurement have had to be radically changed in two respects.

In the first place measurements of the total light must be made, where it has been customary to measure only the light emitted in a particular direction, usually horizontally. To provide a quick and accurate means of making the required measurements, a 90-inch hollow sphere of reinforced concrete has been designed and constructed and its performance as a photometric instrument carefully tested, with very satisfactory results. A preliminary paper describing this instrument has been published; the complete description will be published later in a scientific paper of the Bureau.

The other change in methods of measurement is due to the difference in color of the light given by the new lamps and those formerly standardized by the Bureau. A difficulty arises from the fact that the relative candlepowers of lights of different colors are actually not the same for different persons and under different conditions, and further that the usual standard photometers do not permit of satisfactory comparisons of lights of different colors. In order to establish a permanent and reproducible scale for such measurements, tests of about 160 observers have been made with different types of photometers. Average or normal values have thereby been established, and a method of correcting for the individual characteristics of observers has been tested, which makes it possible to refer to the normal all measurements made by the particular observers. A paper describing the work already accomplished has been published in the Transactions of the Illuminating Engineering Society.

Inter-Laboratory Comparison of Lamps and Color Screens.

The different values which different observers obtain for the candlepower of a light source differing in color from the primary standard can not be eliminated, and the only satisfactory way to standardize such lamps is to take an average of the determinations by a large number of observers, as was done in the recent investigation by the Bureau described above. In addition to those measurements a number of tungsten lamps and color screens were also sent out for measurement by some of the principal photometric laboratories of this country. The results, which have been published as Scientific Paper No. 277, show a good agreement among groups of experienced observers working in different laboratories by the same method and also by different methods. Although the differences among laboratories were small, they were not negligible in precise photometry and they show the importance of making a proper selection of observers. It was found that the average of the Bureau's regular staff of photometric observers happens to be the same as the normal or average of a very large number of people. This work

has placed the photometry of high-efficiency incandescent lamps on a firmer basis than has heretofore been possible.

Performance of Gas-Mantle Lamps.

Ratings of gas lamps have never been standardized as have those of electric lamps, and in cooperation with the American Gas Institute the Bureau is making an experimental study of the conditions which must be taken into account in making such ratings. The measurements made have included determinations of the candlepower and efficiency over a considerable range of gas consumption for several types of lamps at several different gas pressures.

A similar series of measurements has been made in order to compare the efficiencies obtained in burning natural gas with those given by manufactured gas in four common types of lamp, and this work is being extended to determine how the efficiency is affected by differences in heating value and in composition of manufactured gas such as may be furnished under different legal requirements. This latter work has a direct bearing on some very important questions which are under consideration in several States and is a part of the general investigation of the relative usefulness of different kinds of gas which is being undertaken in connection with the public-utility studies of the Bureau.

Testing of Miscellaneous Illuminants.

Tests have been made on several types of kerosene mantle lamps, which are intended to effect an economy in oil lighting comparable with that gained by the use of mantles in gas lighting, and considerable time has been given to answering inquiries from many sources about such lamps.

A complete outfit for an investigation of acetylene burners has been assembled and tested for a large producer of calcium carbide and extensive tests made on different kinds and sizes of acetylene burners.

Tests of several kinds of self-lighting emergency lights for life buoys have been made for the Steamboat-Inspection Service and the Navy Department.

Electrical Testing.

Instruments.—Tests of electrical instruments made for the public during the year included the following: Thirteen voltmeters, 9 ammeters, 11 wattmeters, 19 watthourmeters, 11 voltage transformers, 15 current transformers, 8 pairs of insulated pliers, 4 radio coils, 4 radio condensers, 1 decremeter, 2 complete radio sets, 1 permeameter, 1 iron loss voltmeter, 38 incandescent lamps life-tested, 52 incandescent standards furnished, 93 incandescent standards, 1 lamp regulator, 9 color screens, 3 portable photometers, 16 pentane lamps, 1 Hefner lamp, 1 kerosene mantle lamp, 1 equipment for testing acetylene burners, 4 tungsten lamps tested for spherical candlepower, 9 air condensers, 45 mica condensers, 10 inductance coils, 21 inductances of resistance standards, 2 inductances of measuring instruments, 65 standard cells, 7 volt boxes, 11 potentiometers, 7 resistance bridges, 4 resistance boxes, 7 resistance standards for current measurement, and 95 precision resistance standards.

Tests of electrical instruments made for the Government during the year included the following: Seven voltmeters, 4 ammeters, 1 wattmeter, 4 watthourmeters, 5 voltage transformers; 6 current transformers, 74 dry cells, 64 electric fans, 27 radio coils, 6 radio condensers, 1 wavemeter, 1 decremeter, 200,000 carbon lamps inspected, 1,100,000 tungsten lamps inspected, 3,442 incandescent lamps life-tested, 11 incandescent lamps furnished, 33 reflectors, 7 special signal lamps, 2 portable photometers, 4 air condensers, 10 standard cells, and 1 electric fraud.

Materials.—Materials tested for the public during the year involving electrical measurements included the following: Thirty samples for conductivity tests, 1 insulation-resistance sample, 75 iron samples for normal induction, 14 hysteresis samples, 56 core-loss samples, 82 tubes of radium, 4 tubes of mesothorium, 1 emanation specimen, 7 standard radium solutions, 13 activators, 8 radioactive waters, 13 miscellaneous radioactive substances, and 15 therapeutic preparations.

Materials tested for the Government during the past year involving electrical measurements included the following: Two hundred and ninety-three samples for conductivity, 2 samples of varnish cloth, 26 samples of insulating tape, 9 transformer oils, 144 rubber gloves, 30 tubes of radium, 23 samples of kerosene oil, and 5 samples of signal oil.

The foregoing enumeration of tests does not include a considerable quantity of work done for other divisions of this Bureau. The principal items of such testing were 40 standard cells, 51 pieces of precision resistance apparatus, 30 magnetic tests, and 212 electric lamps. Regular tests have also been made on 20 standard cells which are under observation for a university investigator.

A number of Government departments have been assisted by the testing indicated above. Most of the measurements of electrical conductivity and many of the photometric tests were made for the Panama Canal. The Navy Department has been the largest beneficiary of the photometric testing. Photometric tests are made on samples representing all the reflectors of standard types supplied for use on ships of the Navy and on samples of every shipment of kerosene and signal oils for the Panama Canal. The inspection and life test of incandescent lamps is of direct benefit to all branches of the Government that use electric lamps. In addition to the usual work for the Federal Government, life tests were made of lamps this year for the New York State hospitals and the city of Baltimore. All the Government tests of radium indicated above were for the Bureau of Mines. The radio tests were largely for the Bureau of Navigation of the Department of Commerce, for the Navy Department, and the War Department. The principal interests which have been served by the electrical testing outside of the Government have been manufacturing companies, public-utility corporations, public-service officers, instrument makers, and universities.

The volume of testing shows a considerable increase over the amount done last year. The principal increase has been in radium, samples for conductivity measurement, and electric condensers, the number of each tested having trebled. The value of the radium tested was over $500,000, as compared with about $250,000 the pre-

vious year. The testing of therapeutic and miscellaneous radioactive preparations was begun during this year.

Information Furnished on Electrical Subjects.

A large part of the work connected with the various investigations and tests consists of correspondence, in which scientific and technical information is furnished by the Bureau. Information is also frequently furnished in reply to particular requests. Assistance and advice have thus been rendered on electrical subjects to a number of Government departments, to various scientific institutions, manufacturers, public utilities, universities, and engineers. Besides the miscellaneous information furnished on electric apparatus and methods of measurement, a number of cases of particular importance or interest are mentioned in the following.

Assistance has been rendered the standards committee of the American Institute of Electrical Engineers in the standardization of wire sizes of flexible cables. A study of data on cable stranding showed that the greatest diversity of odd sizes of wire have been used in making up flexible cables. It was found that the situation could be very satisfactorily simplified by standardizing on half sizes in the American Wire Gage, and a recommendation to this effect was adopted by the standards committee. Suggestions were also prepared for a committee of the institute on subjects of research, and the Bureau cooperated in the revision of the standardization rules.

A statement explaining the international annealed-copper standard was prepared for commercial use at the request of one of the large wire manufacturers.

Information has been furnished on dielectric losses and other properties of insulating materials. An investigation to obtain further data would be very desirable. The Bureau is cooperating with the committee on insulating materials of the American Society for Testing Materials in this matter.

A variety of information has been furnished on the subject of radiotelegraphy. Most of this has been for other bureaus of this Department, and has dealt with the installation of radio sending and receiving equipment, the efficiency of radio apparatus, and the design of measuring instruments. Assistance has been given in connection with proposed new radio legislation. Opinions have been prepared on articles which had been written for publication on radio subjects. The handling of correspondence will be facilitated by a circular on radio instruments and measurements which is in preparation. It is the aim of this publication to give as accurate and useful information as possible on radio instruments for the benefit of engineers and amateurs.

Considerable interest has been manifested in the Bureau's work on the correlation of magnetic and mechanical properties of steel. The possibilities of magnetic tests as an aid in determining the properties of many kinds of structures have been considered by the Bureau in correspondence with manufacturers of motor cars and many kinds of steel products. Such structures include aeroplane stays, rails, car wheels, crucible tool-steel bars and rods, crank shafts, steel cables, and pipes. A number of visitors have called at the Bureau for conference on magnetic and allied subjects. Some in-

formation was furnished on the properties of permanent magnets; the Bureau has acquired a representative collection of such magnets. Circular No. 17, Magnetic Testing, has been entirely rewritten and a third edition issued. It is now a valuable compendium of information on magnetic materials and measurements, and describes the magnetic work of the Bureau.

A great many inquiries regarding radium and radioactive preparations were received and answered. The Bureau can, of course, give no information on the healing value of any of the preparations, but has been able to render service by telling the amount of radioactive substances in them. The subjects covered include the testing of therapeutic preparations, water activators, luminous substances, and X-ray apparatus, and the determination of the amount of radium in ores.

In photometry, information was supplied on the methods of measurement of the candlepower of headlights and the absorption of shades. A number of questions have been answered regarding the construction and operation of a large integrating sphere such as has been installed in the Bureau's laboratory. Tests were carried out and suggestions made which led to the development by the Coast and Geodetic Survey of an improved type of signal light for long-range triangulation. An opinion was prepared on the terms under which a city should allow the lighting company to substitute electric incandescent lamps for arcs. Inquiries from various sources were answered regarding kerosene mantle lamps.

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 the 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 standard 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, and hence the Bureau gradually accumulated a considerable amount of information on these questions. Such information on several phases of the work has been collected and published from time to time, and other publications are in preparation. The work in recent years has been considerably enlarged through special appropriations for this purpose.

Standards for Gas Service.

During the past year the work on the standards for gas service has been actively conducted along the line outlined in previous reports including problems as to the heating value, pressure, purity, and candlepower of the gas supplied and the accuracy of meters used for measuring this gas to customers, together with many problems of a technical nature bearing upon the relations between the gas companies and their customers. The demand for the Bureau's assistance on these subjects has been evidenced by the many requests coming from city and State officials and from representatives of the various gas companies concerned. The model ordinances and State regulations proposed in the third edition of Circular No. 32, Standards for Gas Service, have frequently served as the basis from which local regulations are drawn by the officials in charge of such matters. Such proposed rules have been submitted by several State and many city authorities for advice in advance of adoption, and in other cases the interpretation of such regulations concerning gas quality has been submitted to the Bureau by one party or another to controversies where standards were involved.

Other inquiries along closely related lines have referred to matters of laboratory equipment, testing methods, and disputes as to the correctness of test results or as to their interpretation. This work has covered all of the subjects discussed in Circular No. 48, Standard Methods of Gas Testing, a second edition of which has been issued during the year.

Experiments on the Use of Gas.

The studies and investigations of the Bureau on standards for gas and the relative usefulness of gas of different kinds are appreciated not only by public officials but also by gas companies. One evidence of this fact is that the Bureau was invited to present a paper at the International Gas Congress held in San Francisco the latter part of 1915 on the subject of "The substitution of heating value for candlepower as a standard for gas quality." This paper gave a very full treatment of the subject and was exceedingly well received.

This work will be continued during the coming year in order that additional technical information may be collected and experiments made to show the exact relation between the usefulness of gas for practical applications and its heating value and composition. An elaborate series of experiments has already been undertaken to this end. Gases of different quality are being prepared and burned in typical mantle lamps, open-flame burners, cookstoves, water heaters, and similar devices to determine what percentage of the heat in the gas is really useful to the customer under different conditions of application. Very interesting and valuable results have already been obtained showing that certain common practices of gas burning are relatively more efficient than other methods of application also commonly used. The relative usefulness of the supplies of different quality are also being made clear by these experiments, so that from the results it will be possible to state what condition of supply and what standard of gas quality will permit the customer to receive the most useful service for each dollar of cost. From these results it will also be possible to describe to the customer just how the various

types of appliances should be adjusted and operated for greatest efficiency. When it is realized that many operations in which gas is employed utilize only 20 to 30 per cent of the heat available, it can readily be seen that marked improvement in methods of gas utilization may result from a greater knowledge of the proper conditions for its application. The active cooperation of several gas companies and numerous public officials has been assured the Bureau for this work.

National Gas-Safety Code.

The Bureau has continued more actively than in the previous year its work in the preparation of the proposed national gas-safety code which is intended to cover all phases of the production, distribution, and utilization of gases with a view to eliminating dangers to life or health or fire hazards. This code, which was originally intended to be in 5 parts, has been further subdivided into 10 parts, which will be as follows:

1. Manufacture.
2. Distribution.
3. Appliance design.
4. Gas fitting.
5. Appliance installation.
6. Natural-gas wells and field stations.
7. Acetylene.
8. Bottled-gas systems.
9. Blast-furnace, producer, and gasoline gas.
10. Utilization—Information for users.

Parts 1 and 2 deal, respectively, with the production of manufactured gas and its distribution to the premises of the customer. They are therefore primarily of interest to the gas companies and their employees. Part 3, having to do with the conditions to be met in design and construction of gas-consuming appliances, is addressed to the makers of such apparatus and to those handling it either in a wholesale or retail way. Part 4 deals with gas fitting and is primarily addressed to the gas fitter or plumber who is engaged in the installation of the piping, but is also of importance to the architect and builder. Part 5 deals with the installation and adjustment of appliances and is addressed to the same interests as Part 4. Part 6 has to do with the production of natural gas at the wells and its transmission through field pumping stations and high-pressure mains to the limits of the municipality. Part 7 is of primary interest to the users of acetylene and is addressed to the manufacturer of generating and other equipment, the distributor, and the users of the gas. Part 8 deals similarly with bottled-gas systems, Pintsch, Blau, casing-head gas, etc. Part 9 is of interest both to the steel industry and to industrial plants, since it deals with blast-furnace and producer gas, and also refers to the use of gasoline gas. Part 10 is addressed to the user of domestic and industrial gas-consuming appliances and is largely nontechnical in its nature.

The Bureau of Standards in carrying out this investigation desires to serve as a national coordinating agency to the end that the resulting code will be acceptable and adequate not only from the standpoint of the user of gas but also of the casualty and fire insurance

interests, the gas companies and their employees, and the gas appliance manufacturing and selling interests.

The need and value of such a code is so great that the various national organizations dealing with subjects covered by the code have appointed special committees and expert representatives to assist in the investigation. The following organizations are now cooperating in this work: The American Gas Institute, the National Commercial Gas Association, the Natural Gas Association of America, the National Fire Protection Association, the American Institute of Architects, the National Safety Council, and the National Association of Master Plumbers. In order that the Bureau may have the fullest information on every detail of the subjects discussed, the American Gas Institute has appointed 12 committees, 4 in each of the three principal sections of the country—East, Middle West, and Far West. One committee in each district is intrusted with the work bearing upon one of the principal phases of the investigation.

The fourth part of the code, on gas fitting, has been undertaken first, since the need of this portion has been most pressing. A large portion of it has been drafted in a preliminary form and submitted to the American Gas Institute committees, to many boards of underwriters, and to numerous architects, gas fitters, and others. The completion of this part will be possible within the near future, at which time it will be made available for immediate use without waiting for the remaining parts of the code, which require much longer time for their completion.

Economic Importance of the Gas-Safety Code.

The problems confronting the Bureau in its gas-safety code work are of such magnitude and importance that progress is relatively slow under the present circumstances. There is need for a special appropriation for this investigation, which is now being conducted without other support than that which can be granted from the public utility funds of the Bureau. The fund for public-utility investigations, however, is scarcely adequate for work on standards for utility service and other subjects more specifically covered by it. The additional burden of the gas-safety investigations can be borne by the fund only when other work of almost equal importance is interrupted or seriously curtailed. The gas industry and insurance interests are contributing generously the time and skill of their expert representatives in cooperating with the Bureau, and it is often embarrassing to the Bureau to be unable to advance the work as rapidly as would be possible with a very moderate additional expenditure. When one realizes the considerable loss of life and the great value of property destroyed through careless gas-using practices that are largely the result of ignorance or lack of standardization, it is evident that the few thousands of dollars which would be necessary each year to hasten the work on the code would be well expended. It has been estimated that avoidable accidents due to ignorance, carelessness, or faulty installation result in the loss of many hundred lives and the destruction of millions of dollars of property each year. It may reasonably be expected that many of these losses will be eliminated when the code has been completed and adopted throughout the country, both because of the official enforcement of the code and because of its educational value to gas fitters, appliance manufacturers, and the general public.

The code will also serve to unify practice in gas installations and gas-company operation work throughout the country, and it is anticipated that much needed reforms will result. This uniformity of practice will not only tend to greater safety but will also contribute to higher efficiency. In many cases uncertainties in the insurance inspectors' practices and disputes between insurance and gas-company officials can be settled by reference to the code and thus more harmonious cooperation of the two parties can be expected. Already several important instances have been referred to the Bureau for consideration with a view to settlement of differences in insurance inspection practices or questions as to the magnitude of the fire hazard in certain types of gas installations. In this field the services of a recognized national authority are essential in order to standardize the practices and to make available to all the experiences obtained in the various localities. The effort of the Bureau has therefore been directed not only to the preparation of the code, but to the collection of such information as will enable it to serve as a national coordinating agency in this field.

Electric Light and Power Service.

For several years the Bureau has been studying the question of the specifications for electric light and power service, and the requirements that should be made by cities or State commissions of public-utility companies furnishing such service. This study is similar to the studies described above concerning gas service, and the conclusions and recommendations resulting from the study will appear as Bureau Circular No. 56, which is now in press. The principal factors of such service are its quality and reliability, and the accuracy of the meters that measure it. Steadiness of voltage and continuity of service, without which electric lighting is not satisfactory, are phases of quality and reliability that have sometimes been included in regulatory ordinances, while the permissible errors of meters and frequency of testing of meters are almost always included. As the requirements that can fairly be made differ under different circumstances, it has been necessary to prepare more than one set of specifications for cities. Hence, three model ordinances have been prepared, one for large cities, one for medium-sized cities, and one for small cities and towns. In the first the requirements are more detailed and the quality of service required is higher than for smaller places. In the third, requirements are fewer and inspections by the city or town are not contemplated; but the character of service to be expected is specified and there is a basis for further requirements when practicable.

A set of rules suitable for adoption by State commissions has also been prepared, and a digest given of the requirements of all the rules now in force by commissions.

In this work also we have had the cooperation of the electric companies and State commissions, and of the National Electric Light Association and the Association of Edison Illuminating Companies, many valuable criticisms and suggestions having been received. The Bureau has cooperated for years with the meter committees of the above-named associations, and one of the important subjects of the new circular is meter testing and meter accuracy. These specifications have been very thoroughly revised for this publication.

At the invitation of public-service commissions, representatives of the Bureau have attended a number of hearings in various States where proposed rules for the regulation of electric service were under discussion, and have given commissions assistance in formulating such rules. In every case the Bureau seeks, while representing the public interest, to get the utility's point of view also, and has always consulted the utilities concerned before publishing any proposals or suggestions as to rules or regulations.

National Electrical Safety Code.

The Bureau has been engaged for three years in the study of the life hazard in electrical practice and in the preparation of a national electrical safety code. In this work it has had the cordial cooperation and assistance of a large number of the ablest and most experienced engineers of the country, many of whom are connected with the electrical operating and manufacturing companies, and others are engineers and inspectors of State commissions and municipalities. The importance of having a national code, uniform in all the States, is quite as great for safety rules as for rules for reducing the fire hazard, and the advantage of having such a code prepared by an unbiased 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 of machinery, switchboards, and wiring in central stations and substations.
2. Rules for the construction of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.
3. Rules for the installation of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.
4. Rules to be observed by employees in working on or near electrical machines or lines.

This code does not include the matter covered by the underwriters fire code, but 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 such corporations when the code has not been adopted by any administrative body.

The Bureau has made a very thorough study of the diverse conditions under which electricity is generated, distributed, and utilized, and of differences in operating practice in different parts of the country. It has also given very careful attention to the effect of the code on operating and construction costs, and believes that no unreasonable expense will be involved in its use. After preparing a preliminary draft of the code, the Burean has held a large number of conferences in all parts of the country for the discussion of the rules as they have been developed by the extended and thorough study and discussion given to the subject. The rules were published in preliminary form, parts 1, 2, and 3 as Circular No. 54, and part 4 as Circular No. 49. They will shortly be issued complete as a new edition of Circular No. 54, and will then be available for general ex-

amination and trial use. It is expected to revise the rules after a period of experimental use on trial, and the Bureau expects to give very close attention to the results of such trial use of the code.

Introduction and Development of the Code.

The preparation of the national electrical safety code has been found to be a very serious undertaking and has taxed the resources of the Bureau to carry it through. But although the code is now ready for publication, the work before the Burean in connection with its introduction and use will be heavier and require a larger staff of engineers than in its preparation. The special fund provided for the purpose is therefore inadequate and should be increased.

The success of the code depends almost entirely upon its intelligent and reasonable interpretation, and upon its general use throughout the country. The code covers a great variety of subjects, some of which are very technical, and many inspectors and administrative officers of cities and State commissions, as well as the engineers of utility companies, will require assistance from the Bureau in order that the code may be interpreted and applied as intended and with the variations under different conditions that are necessary to make it reasonable and adequate. An addition to the sum available for this work is necessary in order that the Bureau may send engineers to different parts of the country to cooperate with cities and State commissions, and with utility companies who are adopting the code; and to observe the working of the code in practice in order to get information and experience that will be essential in the early revision of the code.

The three years' study that has been given by the Bureau to the subjects treated in the code, and the immense amount of work done by the hundreds of engineers who have cooperated with the Bureau, together with the large number of public conferences held in various parts of the country, probably constitute a more thorough study and discussion than was ever given to a similar set of rules before they were finally promulgated for use. This, together with the trial use of a year or more and the subsequent revision, is expected to provide a body of rules for safe construction and operation of electrical utilities which will be both reasonable and adequate, and which will quickly come into general use throughout the country.

Electrolysis Problem Among Public Utilities.

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

a relatively short time. The property damage caused by these earth currents affects 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 even 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 caused 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 considering 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 when considering further that there are very few water, gas, or lead cable systems which are not more or less subject at some points to electrolytic damage from stray currents, it is possible to better form a 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 of approximately $1,500,000,000, and in addition to this a vast extent of underground lead-cable systems belonging to telephone and electric power companies and to municipalities. In addition to these vast properties in the earth, a considerable part of which may be more or less subject to electrolytic damage, there are possibilities of trouble in the case of bridge structures, portions of steel frame buildings, and piers, which are occasionally exposed to damage from this source. While it is impossible at present to determine with any accuracy the extent of the annual damage to pipe systems by electrolysis, nevertheless the most conservative estimates place it at many millions of dollars annually.

While the total losses due to shortening of the life of underground pipes and cables must be very large, 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, aggregating at the lowest estimate thirty to forty millions of dollars per year in this country. It is true that only a part and probably a small part of this total leakage is due solely to electrolysis, but it is only necessary to assume that a few per cent of this total loss is due to the more rapid developments of leaks caused by electrolysis in order to make the total loss due to this cause run well into the millions annually.

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

Life and Fire Hazard Due to Electrolysis.

It is not alone the property loss, however, or the possibility of such loss 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 transient contact. Actual cases of 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 explosions with disastrous results. Many gas explosions in basements and manholes have occurred, but it is difficult to determine what proportion is due to electrolysis, although undoubtedly many of them are traceable to this cause.

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

Methods of Mitigation of Electrolysis.

While actual dangers resulting from the presence of stray currents on underground pipe and cable systems are great, unfamiliarity with the subject may at times greatly aggravate the seriousness of the case. Because of a general lack of understanding of the electrolysis problem on the part of water and gas engineers, it is easy for a man of inadequate experience and knowledge on the subject or of questionable integrity to play upon the fears of the owners of the underground pipe systems and thus lead to a situation that would compel the expenditure of greater sums under the guise of mitigation of damage than the actual exigencies of the situation would call

for. Further, such persons may, and in not a few cases have, installed so-called mitigative measures which were actually harmful in their effect either to the system to which the measures were applied or to neighboring structures. Altogether more than 25 separate and distinct methods of dealing with the electrolysis problem have been proposed and experimented with from time to time. Some of these are very beneficial when properly used or may become harmful when improperly used; and others, while harmless in their effects on the pipes, may be of no appreciable value and hence a useless expenditure. It is easy, therefore, to appreciate the difficulties confronting the nontechnical man, or even the engineer, who has not given special study to the electrolysis problem; and this emphasizes the need for a more general understanding of the fundamental principles of electrolysis by officials of utility companies operating underground pipe and cable systems.

The Bureau has been studying the electrolysis question for the past six years and has done a large amount of work in connection with it. The first problem investigated was that concerning the effects of electrolysis in reinforced concrete, after which special attention was given to electrolysis of underground pipes. This has included laboratory investigations concerning the effects of electric current on concrete and on metal pipes, tests of pipe coverings, the corrosion of metals in the soil, methods of measuring soil resistance, and various other experimental phases of the work; methods of electrolysis mitigation that have been used or proposed; field studies in actual practice with the application of remedies; and a determination of the cost and results obtained.

Extensive investigations have also been made into methods of electrolysis testing in the field for the purpose of establishing the best methods of procedure in diagnosing the cause of troubles actually experienced, determining the extent to which the underground metallic structures are being affected, and securing engineering data on which to determine the most effective and economical measures that may be applied in any given case to mitigate the trouble.

Recent Electrolysis Work of the Bureau.

The Bureau of Standards has made a number of electrolysis surveys in various cities with the view of making detailed studies under typical conditions, the results of which could be published for the benefit of the public. These investigations have been made in cooperation with utility companies and municipalities concerned and largely at their expense. Complete mitigative systems have been installed by several cities, demonstrating the most effective means of meeting the problem under various conditions. The Bureau makes somewhat detailed tests in each of these places about once a year to make sure that the protective systems are being properly maintained.

Arrangements have been made during the past year to carry out an extended series of experiments in the city of Springfield, Mass., with the so-called 3-wire system of electric railway operation, a system which offers considerable promise for the mitigation of electrolysis troubles under certain conditions frequently met with in cities. The experimental system is now being installed in accord-

ance with plans drawn by the Bureau of Standards and a test of its operation will be made during the fall of 1916.

In addition to the investigation of the problems of electrolytic corrosion proper, the Bureau is doing a good deal of laboratory and field work in the investigation of certain closely allied problems of soil corrosion, many of which are inseparable from complete electrolysis investigations.

Leakage of Current from Electric Railway Lines.

The Bureau is also continuing field work on the subject of the leakage of current from electric railway lines and the possibility of reducing such leakage to a minimum by adopting methods of construction which will greatly increase the resistance between the tracks and the earth. Some laboratory work is being done in this connection, but it is being carried on chiefly in the field with the cooperation of railway companies. Work on the treatment of ties is being done in conjunction with the Forest Products Laboratories.

Advice to Municipalities and Corporations.

In addition to the work of the Bureau outlined above, the results of which are being published from time to time for general distribution, the Bureau renders an important service to the public through the advice given to municipalities and corporations by correspondence. Frequently representatives of utility companies and cities come to Washington for personal interviews relating to various phases of the electrolysis and public-utility problems.

Among the electrolysis reports prepared and published during the past year are the following: Technologic Paper No. 28, Methods of Making Electrolysis Surveys; Technologic Paper No. 52, Electrolysis and Its Mitigation; Technologic Paper No. 54, A Report on Conditions in Springfield, Ohio, with Insulated Feeder System Installed; Technologic Paper No. 55, A Preliminary Report on Electrolysis Mitigation in Elyria, Ohio; Technologic Paper No. 62, Modern Practice in the Construction and Maintenance of Rail Joints and Bonds in Electric Railways; Technologic Paper No. 63, Leakage of Current from Railways; and Technologic Paper No. 75, Some Instances of Track Leakage.

Testing of Telephone Apparatus.

The Bureau has done comparatively little in the testing of telephone transmitting and receiving apparatus and switchboard equipment, but is now taking up this important work more actively and hopes to develop it in an adequate manner. Telephone standards need to be fixed and facilities provided for making tests when required by cities or public service commissions, as well as when requested by telephone companies or by manufacturers of telephone apparatus and equipment.

In making comparisons of instruments, circuits, or lines, the transmission of speech over a standard circuit including two subscriber's sets and two telephone repeating coils of prescribed type, and a standard artificial cable of specified electrical constants, is compared with that obtained when using the telephone apparatus, circuits, or lines under test. The speech transmission in the latter case is then made equivalent to that obtained when using standard terminal ap-

paratus and the standard circuit, by adjusting the mileage of cable until a balance is obtained. Thus differences in the transmission efficiency of lines can be expressed in terms of the losses in transmission in a given number of miles of standard cable. In the case of subscriber's sets, and apparatus such as may be included in the talking circuit when subscribers are in communication, the result is also given in terms of difference in mileage of standard cable giving equivalent transmission.

Such comparisons are not only of interest to the general public, but also to the telephone industry in furnishing guidance as to the performance and suitability of apparatus in use or to be purchased by the operating companies, or as a test of excellence and uniformity of product by the manufacturer; and to the utility commissions which represent both the public and the utilities.

A series of important tests was made for one of the State public-utility commissions in connection with a proposed order of the commission, requiring the establishment of a physical connection between two telephone systems. In this case the Bureau had the valuable cooperation of the several manufacturing companies which had furnished the apparatus employed, as well as of the representative of one of the operating companies involved in the order. In addition, the Bureau obtained the cooperation of the above companies in making further comparative tests of newer types of apparatus and equipment representative of the present-day output.

Standards of Telephone Service.

Preliminary studies have been undertaken to ascertain to what extent the different grades of telephone service required under different conditions can be adequately described in series of standard service specifications. Detailed studies under actual operating conditions, and under the manifold variations encountered in different localities, are necessary before it will be possible for the Bureau of Standards to suggest suitable service standards for telephony similar to those already proposed for gas and electric light and power supply. In this work the hearty cooperation of the operating and manufacturing telephone interests and of the public service commissions having power to regulate telephone utilities is expected. Moreover, such detailed cooperative studies in this and other lines are necessary before public utility commissions can regulate telephone utilities with full justice to all interests concerned.

Inductive Interference with Telephone Service.

The inductive interference with telephone circuits by neighboring electric light and power lines of relatively high voltage is in many places one of the most serious obstacles to good telephone service. The question has been investigated to some extent and rules have been adopted by one State commission and suggested to several other commissions to mitigate the trouble. But it can not be said to have been as thoroughly studied as the importance of the subject requires, nor has a solution been reached which is satisfactory to all the interested parties. It has been frequently suggested that, since it is a national problem of great importance to the public as well as to hundreds of power and telephone companies, and becoming every year more im-

portant, and especially since it is closely related to some of the engineering questions the Bureau of Standards has been engaged upon, it would be a proper subject for the Bureau to investigate in a thorough manner, with the cooperation of the utilities concerned as well as electrical manufacturers and State commissions. One of the remedies most frequently proposed is to keep the power and telephone lines separated a sufficient distance where it is practicable; another is to transpose the lines properly and to construct the power lines so well that partial grounds shall be as infrequent as possible. These measures of precaution should be specified as definitely as possible, so as not to cause any greater trouble and expense or greater limitations on service than necessary. The Bureau stands ready to undertake such an investigation, if it is generally agreed that it should do so, and sufficient funds are made available for the purpose to enable it to be done in an adequate manner.

Lightning Protection.

A study of the protection of buildings against lightning has been in progress for several years, and a publication on the subject has been issued as Technologic Paper No. 56. This includes a full discussion of the methods of lightning protection, the results of experience as shown by vital statistics, and the records of fire-insurance companies, and other interesting information. The work is being continued and specifications will be prepared for protecting different kinds of buildings so as to make it easier for architects and owners who wish to place lightning protectors on various types of structures to do so as efficiently and economically as possible. The Bureau has conferred with the manufacturers of lightning-protection material and hopes to have their further cooperation in preparing specifications for protection systems.

Cooperation with the Underwriters' Laboratories.

The Bureau cooperates with the Underwriters' Laboratories in some of its work, and has an agreement whereby appeals may be made to the Bureau in certain cases where the rulings of the laboratories are protested. The Underwriters' Laboratories is a private institution but is performing a public function, and it is thought desirable that an appeal to a public body should be possible without resort to courts of law, especially since the questions at issue are usually of a scientific or engineering nature.

The first case under this arrangement to come to the Bureau was a joint appeal by the Underwriters' Laboratories and a manufacturer of a renewable cartridge fuse, a device for protecting electric circuits. The Bureau made a thorough investigation of various types of approved nonrenewable fuses as well as the renewable fuse under discussion, and inspected many fuses in service. It also conferred with insurance and municipal inspectors and engineers who have had experience with various types of inclosed fuses. Some of the experiments were made in the Bureau's laboratories, and others in power stations where a large amount of power was available for the larger sizes of fuses. Most of these tests were made in conjunction with certain of the fuse manufacturers. The question was decided in favor of the Underwriters' Laboratories and a full report has

been prepared for publication, including a full digest of the experiments and all the evidence gathered, so that the public will be able to judge as to the merits of the question at issue. The case is of great importance to manufacturers and to the public.

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

In many States the public-service commissions have set standards of service, and the Bureau has cooperated with most of those that have done so. In other States the railroad or public-service commissions have taken no action in the matter, although having authority to do so. 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 the matter with enterprise and understanding. 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 even in such cases 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 each case and relieve the municipalities of all 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 commission for hearing and adjudication, the State commission would be better able to serve all the municipalities of the State, and the municipalities would enjoy in large measure the advantages as well as the responsibilities of home rule without its greatest disadvantages.

But for most cities it is a difficult matter to judge as to the quality of service rendered by its utilities. The studies made by the Bureau, however, are not sufficient to enable it to do as much as ought to be done, and some of the most important subjects in this connection have not as yet been taken up.

It will obviously never be practicable for any State commission or city to handle these questions alone. Though they possess large and able engineering staffs or employ specialists for each separate problem, the question of what is good service or whether the service in any given case is adequate, safe, and satisfactory can only be settled 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 in a large way. The Bureau of Standards has been doing this for several years in a somewhat experimental way to test the desirability and acceptability of the method. The success and approval which the work has met so far seem to justify its expansion.

Necessity for Increasing the Public-Utility Work of the Bureau.

The sum available for the public-utility work of the Bureau during the current fiscal year, including a special appropriation for the safety work, is $55,000. Many of the States spend more than this, and some States five or ten times as much. The people of the

United States spend about $2,000,000,000 a year for the service of the public utilities, or $20 per capita per annum. This includes the telephone, gas, electric light and power, electric railway transportation, and miscellaneous utilities, not including the steam railways. The States through their public-utility and railroad commissions spend $4,000,000 a year regulating the utilities and railroads, and the cities a large amount in addition. A considerable sum could profitably be spent annually in an efficiently conducted cooperative study of the conduct of such utilities, defining standards of service, preparing safety rules, assisting in local studies as to service, acting as referee or adviser in cases of dispute, serving as a clearing house of information on all public-utility and associated engineering questions, helping to secure uniform methods of accounting, especially where public-service commissions are not yet established, carrying out laboratory tests and investigations to answer difficult questions, and making it possible for rules as to service and safety to be kept revised up to date, after they have once been formulated and adopted. Such work carried on with the cooperation of the utility companies and commissions requires a great many conferences and discussions and the harmonizing of differences of opinion. Many such differences of opinion are due to lack of precise information. Often experimental or other studies clear up such differences and bring about uniformity of practice. A Federal bureau well equipped with men and apparatus, and permitted to work in the very wide field of public utilities (outside of railroad transportation and such subjects as the Interstate Commerce Commission is concerned with) can accomplish great good for the public. It does not appear to be overestimating the value of such work to say that an average benefit equivalent to 5 per cent of the sum now paid for the service would result. It seems conservative to suppose that such benefit in improved efficiency and better service would seldom be less than 2 or 3 per cent and sometimes as high as 10 per cent. Five per cent of $2,000,000,000 is $100,000,000 per year, and this appears to be a reasonable estimate of the possible value of the service being considered, assuming such service to be efficient and ample. One cent a year per capita is only a hundredth part of this sum, and this does not seem too much for the people to spend cooperatively through the Federal Government to accomplish this result. At present the Bureau of Standards is spending about one-twentieth of this, and has accomplished enough to show how valuable such work is. If the funds available for this work could be gradually increased as the work developes until the total was five times as much as at present, the sum would still be less than several of the larger States are spending alone, and yet the results of the work being made available for every State would yield in the aggregate a large return to the people. Considering the enormous cost of public-utility service, it does not appear to be desirable to continue spending so much without a greater effort to derive the benefits possible from a just and adequate system of public-utility regulation.

But the money value of proper regulation of the utilities is not the only benefit to be derived therefrom. The increase of safety and reduction of accidents is another consideration difficult to estimate in dollars and cents. Still another advantage, more difficult to ap-

praise but not difficult to appreciate, is the favorable influence on State and municipal government. Unregulated utilities sometimes control municipalities; improperly regulated utilities are sometimes forced to resort to questionable methods in self-defense. Public officials charged with the duty of regulating public utilities, but not provided with the means of doing it equitably and effectively, are at a serious disadvantage and frequently can accomplish nothing. The eagerness with which public officials with whom the Bureau has cooperated in the past have sought reliable information and their appreciation of the work of the Bureau indicate that if this work could be greatly enlarged and made available in a larger number of cities and States, it would be of immense economic importance and by establishing a better understanding between utilities and the representatives of the public would have a salutary effect upon municipal government.

4. LIGHT AND OPTICAL INSTRUMENTS.

[Wave length of radiation (visible and invisible); color, relative emissivity, reflectivity, and absorption of materials for light and other radiation; transparency; and radiation constants, including experimental researches required in determining the optical constants of materials and of radiation; in developing optical standards of performance or quality of optical products for manufacturers, technical experts, and research laboratories; and in standardizing the measurement and specifications of colors for such industries as dyes, paints, ceramics, paper, inks, etc.]

Determination of Standard Wave Lengths.

The work of determining standard wave lengths was undertaken to study some characteristics of the lines in the spectrum of the iron arc and to establish a satisfactory system of standard wave lengths. The wave lengths and other characteristics of spectral lines must be well known if spectroscopic analysis is to be successful. Much uncertainty still exists concerning these characteristics, and to remove ambiguity is of primary importance in a system of standards.

During the past year the measurement and reduction of wave lengths were finished for the whole region of the spectrum in which secondary standards have been accepted by the International Committee on Wave Lengths of Light. This region extends from the ultra-violet (3233A) to the deep red (6750A). The angstrom unit is defined as the wave length of the red cadmium line divided by the number 6438.4696. The abbreviation for angstrom is A and its length is one ten-thousandth of a millimeter. Between these limits over 400 lines in the arc spectrum of iron were measured by interferometer methods. As far as possible sharp lines of different intensities were measured at nearly regular intervals in this region. The accuracy of these measurements is one part in several millions. The wave lengths of other spectra photographed together with these standards can be accurately obtained and the corresponding chemical elements identified. The Bureau has applied this method to the analysis of alloy steels, various ores, and slags.

The sharpness of about 600 iron lines was investigated by means of the interferometer, and the relation of sharpness to intensity and change of wave length due to pressure or other causes was sought. The results of this work on the spectrum of iron were published in Scientific Paper No. 274.

Infra-red Photography.

The Bureau has begun to explore the infra-red regions of emission spectra by photography. By means of photographic plates stained with dicyanin to make them sensitive to infra-red radiations the arc spectra of iron, nickel, copper, and cobalt have been recorded far beyond the visible limit in long wave lengths. In the case of iron, about 60 lines were found between 8000A and 9260A. In the nickel arc, about 25 lines were photographed from 8000 to 8970. About 20 lines were found in the copper arc from 8000 to 8680 and over 100 lines in the cobalt arc from 8000 to 9600 angstroms. By means of improvements in technique and longer exposures it is hoped that still longer heat waves can be registered photographically. The importance of this work can not be overestimated. At present very little exact information about wave lengths and general characteristics of emission spectra of the chemical elements exists for radiation of wave lengths longer than the yellow light.

Spectroscopic Analysis.

The development of a method of making quantitative spectroscopic analyses has been continued. The arc spectra of samples of steel containing chromium, titanium, etc., have been examined in connection with quantitative determinations of the elements present made by chemical methods. When more spectroscopic and chemical examinations have been compared it will be possible to make quantitative analyses spectroscopically with a fair degree of accuracy and ease.

A number of qualitative and comparative spectroscopic examinations of furnace slags and retort residues were made for zinc producers. Eleven samples of zinc ore were also analyzed. The object of this work was to find sources of gallium, indium, and germanium. An ore from Missouri was found to be rich in both gallium and germanium. The spectroscopic method for the detection of these rare metals seems to be easier and more sensitive than the chemical method.

Some samples of tin were examined for the metallurgical division of this Bureau to test the applicability of the spectroscopic method to the detection of impurities. It was found possible to determine the zinc content of tin with some accuracy when only 0.1 per cent of zinc is present.

Interferometer Apparatus.

Various metals were deposited upon quartz plates in a vacuum by high-voltage alternating electrical discharge. Thin films of iridium, palladium, platinum, nickel, and silicon were thus prepared and examined for reflecting power and transparency to ultra-violet light. Silicon was found to be quite satisfactory and is a solution of the problem of constructing an interferometer to work with extremely short wave lengths. Such an interferometer will be used to determine secondary standards of wave length in the extreme ultra-violet part of the spectrum of the iron arc.

An effort has also been made to find the metal most suited to the construction of interferometer mirrors which may be used in the red

and adjacent infra-red portions of the spectrum. Here, again, a compromise must be made between reflecting power and transparency of the metallic films for these particular radiations. Silver, gold, platinum, and copper have been tried thus far.

Rare-Gas Discharge Tubes and Spectra.

Due to conditions in Europe, the Bureau has been called upon to a much greater extent than formerly for electrical discharge tubes containing rare gases. Many helium, neon, and hydrogen tubes have been made and furnished for scientific research.

Some work has been done on the spectra of the rare gases. The wave lengths of 24 yellow and red (5852A to 7245A) radiations from neon gas have been accurately measured with the interferometer in terms of the fundamental standard wave length of cadmium (6438, 4696A). Neon, krypton, and xenon emit many sharp, homogeneous radiations, which will serve as excellent secondary standards. These spectra are preferable to the cadmium radiations in some respects and will be of great value after they are carefully calibrated in terms of the latter.

Miscellaneous Tests.

Miscellaneous tests have been made on the ultra-violet transmission of Pyrex and Jena beaker glass, various glasses for spectacle lenses, cottonseed oils, and water cells.

Constants of the Saccharimeter.

The saccharimeter as a scientific instrument for the analysis of the purity of sugar is the accessory by means of which the buying and selling of sugar throughout the world is accomplished. The results given in the preliminary announcement a year ago regarding the investigation of the basis of standardization of the modern saccharimeter have been fully confirmed and recognized by investigators. Because of the importance of this problem, elaborate precautions were taken to avoid all errors that might vitiate the results obtained. The Bureau's investigation, which pointed out the existence of an error of over one-tenth of a per cent in the testing of all sugars, has aroused such interest in the subject that the article describing the work (Scientific Paper No. 268) has been published in Spanish and is now being translated into German. The international discussion of the Bureau's work, for which purpose a commission was appointed several years ago, has been temporarily postponed.

Rotation of Quartz Crystals at High Temperatures.

Preliminary measurements have been made on the natural and magnetic rotations of quartz at various temperatures from room temperature up to 1,050° C., and for light of various wave lengths. Special furnaces have been constructed for this purpose. The results so far obtained indicate that it will be necessary to modify the theory regarding these phenomena.

Optical Rotation of Dextrose (Grape Sugar or Glucose).

Dextrose (grape sugar or glucose) is of wide occurrence in nature and is manufactured in relatively large quantities. The analysis of dextrose, either alone or in mixtures such as foodstuffs, depends upon an accurate knowledge of the properties of the pure substance. Two methods of analysis are available, one depending upon the use of the polariscope and the other upon the power of the dextrose to reduce and precipitate copper from an alkaline solution. The study of pure dextrose has for its purpose the standardization of both of these methods. To control the polariscopic method, the weight of pure substance required to rotate 100° S. (or 100 per cent) on the quartz-wedge saccharimeter has been determined. By the use of these data, it is possible to analyze glucose in much the same manner as sucrose. In order to control the reducing sugar method, the purified substance is issued as one of the standard samples of this Bureau.

In addition to the work on the saccharimeter, the rotation of the plane of polarized light has been determined for light of a single pure color, namely, green light of wave length 5,461 angstroms. The rotation on both the polariscope and the saccharimeter is not strictly proportional to the quantity of dissolved substance, and accordingly a table was prepared which indicates the corrections to be applied.

Clarification of Solutions of Raw Sugars and Molasses.

Some years ago the Bureau completed an investigation upon the composition and properties of basic lead acetate, which is the substance used in the clarification of raw sugars for testing. It is now proposed to apply the information obtained to the problems of clarification. There is a large residual error in raw sugar analysis, due to the volume of the lead precipitate, which reduces the apparent volume in which the sugar is contained. An investigation is now under way to study the methods of avoiding this volume error as well as the effect of the basicity of the basic lead acetate used.

Solubilities of the Sugars.

The solubilities of the sugars are fundamental questions which have an industrial as well as a scientific importance. The quantity of cane sugar which a given process will yield depends much upon the solubility of the sugar. If this is known accurately and the effect of other substances present is studied, additional light may be thrown on the problem of molasses formation. An investigation of the solubilities of the pure sugars and finally the effect of each upon the solubilities of the others is now under way. It is hoped to extend the investigation to include the effect of mineral salts upon these solubilities.

Specific Gravity of Molasses.

The Bureau has made a preliminary investigation of the various procedures for the determination of the specific gravity of molasses because of the variations which exist in the results obtained by different methods and by different analysts using the same method. It is hoped that this work may be continued in order that an accurate method may be recommended for use.

Referee Work in Molasses Testing.

The work inaugurated a year ago, of acting as referee between the buyer and the seller of low-grade molasses, has been continued. Samples representing seven cargoes were tested. After testing a number of accepted methods and making certain modifications, a method was obtained which gave fairly consistent results. The importance is apparent of having a standard method of testing in this work, with all the details for carrying it out rigidly specified.

Supervision of the Customs Laboratories of the Treasury Department.

In the report of last year mention was made of the fact that a marked improvement was noticeable in the accuracy of the work of the customs sugar-testing laboratories. This was due to the installation of an improved saccharimeter and other apparatus developed by the Bureau. Since the entire revenue on sugar is collected through these laboratories, it is of great importance to the industry that the difference between their tests be as small as science can make them. A very small difference is sufficient to give the refiners at one port a decided advantage over their competitors at another port. It is, therefore, gratifying to note that during the past year there was a further decrease in these differences, and that the courts recognized the agreement between the port laboratories and the Bureau as being an uncontrovertible answer to the claims of importers that the tests at certain customs laboratories were too high. The work of assisting the Treasury Department in improving the equipment, personnel, and efficiency of its general customs laboratories was continued with satisfactory results.

Assistance to Special Industries.

Owing to the increasing number of requests from manufacturers and chemists concerning polariscopic work, a member of the polarimetric laboratory visited one of the larger manufacturing cities and made a preliminary survey of the laboratories in that city. The use of the polariscope is constantly being extended into new fields; so much so that only by studying its applications in the industries and special laboratories can the Bureau maintain itself in a position to be of the best possible assistance.

Standard Samples.

A total of 87 standard samples of sucrose and 9 samples of dextrose were sent out. These two substances were for the most part requested by manufacturers and scientists for the standardization of saccharimeters and for standards to determine the heat value of fuels, etc.

Polarimetric Tests of Raw Sugars.

A total of 1,243 samples of raw sugars were tested. About one-half were tested for the percentage of sugar present as shown by the polariscope. The other half, in addition to testing for the percentage of sugar, were tested for the percentage of moisture present and a correction applied for it. The samples were mainly from the large centers for sugar importations, and the results were used to check the accuracy of the customs laboratories.

Polarimetric Tests of Molasses.

A number of samples of molasses and sirups were tested. The character of the test varies with the material and the purpose for which it is to be used. Several samples of good grades of sirups were tested for the Government Printing Office, where the material is used in the preparation of ink-roller composition.

Miscellaneous Polarimetric Testing.

The increase in the diversity of the information and tests requested by the general public showed a marked increase. This has been very gratifying, as it indicates a wider dissemination of knowledge regarding the Bureau and a ready response on the part of industrial concerns to take advantage of the opportunity which is afforded them. About 1,500 cover glasses for polariscope tubes were tested for optical homogeneity. These plates are used to confine the sugar solution in the polariscope tube while it is being read in the saccharimeter. They must be sufficiently free from strain to answer the most delicate optical tests. Until recently they have been manufactured only in Europe. With the assistance of the Bureau, an American firm has succeeded in producing satisfactory glasses, and this country is, therefore, no longer dependent on Europe for its supply. Sucrose was furnished for the preparation of the pure carbon with which carbon steels were made. Sucrose solutions of accurately known concentration were used as standards for viscosity measurements. Saccharimeters and quartz-control plates were tested and information furnished regarding standard single-colored light sources, high-vacuum pumps, and high-vacuum gauges.

High-Vacuum Pump.

A new vacuum pump, rapid and certain in its action and capable of producing high vacuums, has been developed by the Bureau during the past two years. Heretofore practically all the pumps of this type have been developed and manufactured abroad. There has been an insistent demand for them both for scientific and commercial purposes. The principal objection to pumps now available are (1) their liability to get out of order, and (2) two pumps working in series are always necessary. The pump developed by the Bureau has been thoroughly tested during the past year. It has no rotating air-tight joints, and will produce a vacuum the pressure in which is represented by the difference of one-hundred thousandth of a millimeter in the height of two columns of mercury. However, its most important improvement is in the elimination of one of the two pumps which have heretofore been necessary in the production of high vacuums. For the first time a pump is now available which will exhaust directly from atmospheric pressure to a high vacuum.

Investigation of the Large Electromagnet.

In utilizing the large electromagnet for optical purposes it has been found necessary to make a detailed study of the strength of the magnetic field. The intensity of the force along the axis has been measured under different working conditions, using various shaped pole pieces, various sized perforations, various separations of the pole pieces, etc. The strength of the magnetic field is usually determined by measuring the electrical resistance of a coil of bismuth wire

placed in the field. In the course of the work it was found that the temperature-resistance curve of the bismuth spiral had shifted, and it was necessary to make a recalibration. On account of the uncertainty of the measurements due to this change in the bismuth spiral, which seems to occur from time to time, apparatus is now being installed for measuring the field strength by an independent method, using an exploring coil calibrated by a known mutual inductance. It is expected that by having two independent methods of measuring the field errors will be eliminated and a higher degree of precision attained. In addition a thermostat has been constructed between the poles of the magnet in order to control the temperature of substances while their magneto-optical rotation is being studied.

Investigation of the Color of Cottonseed Oil.

As mentioned in the last report, the Bureau has undertaken, at the request of the Society of Cotton Products Analysts, and the Inter-State Cotton Seed Crushers' Association, and with their assistance, an investigation of the color of cottonseed oil, for the purpose of establishing satisfactory methods of color grading that product. Actual cooperative laboratory work on this investigation was begun in July, 1915, and was carried on under the immediate direction of the Bureau's expert in charge of color standardization. The chief features of the work to be attempted, as agreed upon between the Society of Cotton Products Analysts and the Bureau in May, 1915, were the following:

(1) A comprehensive color analysis survey of representative samples of cottonseed oil in order to obtain fundamental data on which to base further work.

(2) Time tests of the permanency of the oil color, particularly under conditions most favorable to its permanency, with a view to establishing sealed certified color standards of the oil itself.

(3) The design of a colorimeter suitable to compare samples with the color standards.

This investigation is not yet completed and accordingly no definite report can be made on it. However, the results to the end of June, 1916, may be summarized as follows:

(1) Forty-six samples of oil submitted in June, 1915, have been examined and intercompared by spectrophotometric analysis (measurements of the transmission for light of different colors). The results show several different types of spectral transmission. Eight samples of crude oil and 10 samples of prime wintered oil have been similarly examined. The spectral transmission of the oil has been compared with that of the colored glasses formerly used to grade it.

(2) The essential results of the permanency tests are the following: (*a*) The permanency of the color depends to some extent upon the sample; the color of oils having absorption bands for orange-colored light is less permanent than that of those not having such bands. (*b*) Fading is caused by the joint simultaneous action of light and air; protection from either light or air greatly inhibits the fading. (*c*) The best method of sealing is in all glass cells from which the air is completely exhausted before sealing. (*d*) The color of vacuum sealed cells of oil of the more permanent type kept in the

dark has been observed to be constant for periods of six months to one year. (*e*) There is generally a period of change immediately after sealing, followed by a period of several months of constancy. (*f*) Cells have been observed constant in color during several weeks of exposure to direct sunlight, but 15 to 25 weeks of exposure has caused a quite noticeable change.

(3) An improved type of variation of thickness colorimeter has been designed and an improvised form of it tried in practice. Complete plans for a perfected model of this instrument are now in the hands of the instrument maker.

By invitation, the Bureau's expert in charge of this investigation presented a preliminary report on it at the annual convention of the Inter-State Cotton Seed Crushers' Association, Memphis, Tenn., June 7, 1916.

Specification of the Color of Butter and Oleomargarine.

Several conferences with oleomargarine manufacturers and dairymen have been necessary to explain the specification mentioned in last year's report. Samples have been tested for Swift & Co. in terms of this specification. By invitation, the Bureau's representative presented this subject to the Ohio State Dairymen's Association, Columbus, Ohio, February, 1916. It should be noted that the Bureau has no interest in the enactment of legislation on this subject, but has merely complied with the requests for technical information received from manufacturers of butter and oleomargarine.

Color-Blindness Tests.

About 30 individuals have been tested for color blindness incident to the photometric observations they were making at the Bureau. Considerable time has been given to the study of methods of color-blindness testing, and the selection and installation of instruments for this purpose. The Bureau has been requested by the Navy Deparement to standardize the colors used in color-blindness tests and this investigation is now pending.

Spectrophotometry.

Only minor changes have been made in the routine methods of spectrophotometry for determining the transmission for light of different wave lengths established last year, but further tests of precision and accuracy have been made. These showed a very satisfactory precision for all colors except the blue and violet. There is urgent need for improvement in the precision of measurement of the intensities of these colors, and it is planned to construct, during the coming year, new apparatus to meet this need.

Monochromatic Colorimeter.

Any color sensation (except purple) may be "matched" by a mixture of light of some one properly selected wave length (color) with a properly selected proportion of "white light." From a philosophical point of view this is the most natural and the simplest method of defining a color, but the experimental difficulties and uncertainties of putting it into practice have been considerable. The chief trouble has been due to the necessity of making a photometric comparison between colored light and white light in each color de-

termination. To eleminate this uncertainty in routine work, a colorimeter of a new type has been designed and partly constructed. It has been set up in an improvised way and tested qualitatively. A complete instrument adapted to precise work is now to be constructed, after which quantitative tests of its functioning will be undertaken as soon as possible. A technical description of the essential features of the proposed instrument has been published.

Tests of the Transparency of Tracing Cloth and Paper.

The method mentioned in last year's report has been continued in use for the testing of tracing cloth and has also been extensively applied to the testing of nearly opaque envelope papers, where it has given apparent satisfaction. A description of the method has been published.

Calibration of Photometric Wedge.

A photometric wedge of extreme range was calibrated for the Bureau of the Public Health Service, incident to a research being conducted by that bureau. This calibration was made in the apparatus in which the wedge is to be used.

Determination of Thermal Expansion Coefficients by Interference Methods.

The expansion of small specimens of material due to temperature changes is most conveniently measured in terms of the wave length of light by means of observations on "interference fringes." During the year new and improved apparatus for the control and measurement of temperature has been installed and is now being successfully used. A test of the expansion of furnace slag was made by this method. Tests of the relative expansion of different parts of steel rails have been made incident to the Bureau's investigation of the causes of failure of rails. One report on this subject has been made, while other tests are still pending. Notable improvements have been devised in the methods of observation, and improved forms for standards and samples have been designed. It is expected that descriptions of these can soon be published.

Investigation of Methods of Measuring Turbidity.

Inquiries for information concerning the turbidity of such various mediums as ocean water, air, cottonseed oil, and human spinal fluids show the value and importance of work in this field. There is considerable demand for a standard of turbidity and still more for a simple instrument of more precision than the ones at present in use. To meet these demands a careful investigation of the properties of turbid mediums is in progress and a new turbidimeter has been designed and is nearing completion in the Bueau's shop.

Report to the Coast Guard on an Investigation of Fog.

The Bureau has contributed to the Report of the Coast Guard a short description of the study of fog made by Bureau scientists aboard the ice patrol cutter *Seneca* during the May cruise of 1915. Very few are aware of how fog, rain, and clouds or any kind of condensation are formed or that anything more than water is required.

A brief introduction was therefore included, stating the general properties of fog.

The results have suggested the possibility of seeing above fog—that is, of an observer on the masthead of one ship seeing a flag or a powerful light on the masthead of a near-by ship. This possibility will be further tested through the courtesy of the Navy Department. The results on nucleation have proved of value in connection with recent theories of atmospheric electricity.

Information Furnished Relative to Color and Transparency of Materials.

Information has been furnished by correspondence and by personal conferences to scientific institutions, manufacturers, Government bureaus, and individuals on subjects pertaining to color standardization and measurement.

Investigation of Strain in Chemical Glassware by Optical Methods.

In conjunction with the investigation of chemical glassware which has been undertaken by the chemical division of the Bureau, the quality of annealing, as indicated by the residual strains, has been examined in about 450 flasks and beakers. The similarity of the amounts and location of the strains in all the beakers of each make indicates that the strain is introduced in the process of manufacture of the vessel. It is expected to correlate the heat resistance of the glassware with the strain determination.

Central Aberrations of Lenses and Lens Systems.

The work on the aberrations which affect the definition of optical systems near the center of the field has been completed. The method has been described and illustrative data and curves for 20 lenses given and discussed. The paper is now ready for publication.

Optician's Primary Standard Trial Set.

An optician's trial set of 132 lenses has been measured and corrected to a very high degree of accuracy. This set is in the possession of a spectacle-manufacturing firm, and it is hoped that it will in a large measure do away with the confusion arising from the haphazard filling in of single lenses, often inaccurate, in the trial cases of practicing opticians.

Construction of Spherometer.

To perform the measurements on the optician's primary standard trial set, a new spherometer was constructed, and its performance studied. Thus a spherometer of great precision has been obtained.

Rebuilding of a Large Spectrometer.

A large spectrometer, supposed to be very well made and exceedingly accurate, was found on investigation to be worthless where precise measurement was desired. The instrument was redesigned and reconstructed in the Bureau's instrument shop, and it is now hoped to measure angles with it to the very high degree of precision required in the work.

Refractive Indexes.

The extent to which a ray of light is deviated from its normal path when passing through a transparent substance of given dimensions is called the refractive index. This quantity is often sufficient to determine the substance.

Refractive index measurements were made of glass and other substances as a result of a number of requests.

The potentiometer installation has enabled the determination of indexes of refraction of liquids to a unit in the fifth decimal place (0.00001).

Several refractometers were calibrated for various departments of the Government and their correction curves determined.

For accurate temperature measurement, such as is required in the determination of the refractive indexes of liquids with a high temperature coefficient, a thermometer is very inefficient. For this purpose a potentiometer was installed. The method of making thermocouples was studied, and three were constructed, which give excellent results.

Computation of a 6½-inch Telescope Objective.

A telescope objective, 6½ inches in diameter, was computed and is now in process of construction. This objective has very fine corrections, and will serve as a standard of optical performance. In its construction great care is being taken to follow the computed design exactly.

Testing of Optical Systems.

The testing of optical instruments has been done largely for the various Government departments. These tests include various types of instruments, such as microscopes, photographic lenses, searchlight mirrors, binoculars, periscopes, telescopes, projection lenses, and gun sights.

A complete test of a photographic lens was performed at the request of the manufacturers.

An examination was made of the submarine periscopes in use by the Navy Department. It was found that the instruments made in this country are equal, if not superior, to those of foreign make.

Information Furnished on Optical Systems.

Many requests have been received for information and advice regarding optical instruments. The practicability of projected optical systems has been discussed with various people, and much valuable assistance has been rendered in this direction.

Considerable time has been devoted to consultation work with the various departments of the Government, as well as with the different divisions of the Bureau, with reference to the design, specifications, testing, and use of optical systems. Many measurements have been made, furnishing data for the construction in this country of repair parts which previously had to be imported from abroad.

Radiometry.

During the past year investigations have been continued in connection with the improvement of instruments for measuring radiant energy, especially instruments for measuring it in absolute value, and

for measuring feeble radiations such as are received from stars. New designs of instruments have been tested, including a bolometer receiver, at the back of which is placed a thermopile receiver, or several bolometer receivers placed back of each other. Such combinations were found efficient, due to the fact that when a thin radiometer receiver is exposed to radiant energy it becomes warmed and, in turn, emits a very appreciable amount of energy.

Investigations are in progress on thermocouples of finely drawn wire of bismuth alloys. The sensitivity of the ironclad galvanometer has been increased more than ten times. The sensitivity of the radiometric outfit as a whole has been increased more than twenty times, which is the minimum increase in sensitivity (mentioned in the previous investigation of the radiation from stars, reported upon a year ago) that will be required in order to do much successful work in stellar radiometry.

During the past 18 months much time has been spent in attempting to obtain an accurate agreement in temperature measurements on a black body as determined by means of thermocouples and an optical pyrometer, both of which were calibrated at the melting points of metals. The novelty in the optical pyrometer consists in having two lamps, either one of which can be brought into the line of sight of the telescope. It takes but little additional time to measure the temperature with the extra lamp, which serves as an important check upon the temperature measurements. Important data were obtained, using absorption screens of copper nitrate solutions and orange-colored Corning glass, which combination gives a very narrow transmission band more favorably situated in the spectrum than obtains with the ruby glass commonly used in the eyepiece of optical pyrometers.

Constants of Radiation of a Uniformly Heated Inclosure.

In last year's report attention was called to the completion of an investigation of a new instrument for evaluating radiant energy in absolute measure. These data have now been published, giving a value of $\sigma=5.72\times10^{-12}$ watt cm^{-2} deg^{-4} for the coefficient of total radiation.

The constants of spectral radiation, published some years ago, were recomputed, using a new calibration curve, the new values being A=2894 and C=14369 micron degrees. These data indicate that Planck's constant, h, is of the order of $h=6.56$ to 6.57×10^{-27} erg sec. This is close to the observed value obtained from photoelectric measurements.

All these data are in agreement within the experimental errors of observation, which have been reduced to 0.5 per cent as compared with experimental errors of several per cent which obtained only a few years ago. These data are of fundamental importance and apparatus has been assembled for continuing the work, having the instruments in a vacuum, the radiator being an inclosure surrounded with molten metal.

Standards of Spectral Radiation.

Frequent requests have come to this Bureau for data on the distribution of energy in the visible spectrum of a standard source of light. The acetylene flame appears to be a promising light source

having high intensity and a white color. It differs from a solid radiator, e. g., a tungsten lamp, in that it is regenerative and, hence, does not require recalibration after long usage.

During the summer of 1913 the energy distribution in the spectrum of the acetylene flame was determined with two different kinds of spectroradiometers, and during the past year further data were obtained with a third instrument. The data have just been published, giving what is considered the best-known spectral energy distribution of a light source.

Visibility of Radiation.

In many photometric, spectrophotometric, and other investigations it is important to know the response of the eye to radiation stimuli of different wave lengths, i. e., light of different colors. It is also important to determine the average response for a large group of observers. The Bureau's large corps of investigators insured an extensive and varied group of subjects, and its facilities for measuring the light stimuli radiometrically were important reasons for undertaking the investigation.

To date the visibility of radiation of about 130 subjects has been determined, including individuals who are blind to certain colors, e. g., red-blind. The data thus far obtained indicate that the total number of individuals examined might be still further increased to insure obtaining an average value of visibility.

Spectacle Glasses for Absorbing Infra-red Rays.

In last year's report attention was called to the interest taken by manufacturers in protecting the eyes of workmen from infra-red rays by suitable spectacle glasses which absorb the infra-red. During the past year considerable time was spent with success in testing commercial glasses for the public as well as in original investigations.

Physical Photometry.

A logical sequence to the development of a sensitive thermopile and a well shielded galvanometer, mentioned in previous reports, was a test of these instruments for photometric work. By interposing between the thermopile and the source of light to be tested a screen which is opaque to all the ultra-violet and infra-red radiations, and which transmits the visible radiations in proportion to the visibility curve of the average normal eye, the device can be used as a photometer. Measurements on an incandescent lamp made with this instrument and with a visual photometer were in remarkably close agreement, indicating that the device may be of value in certain kinds of photometric work.

Subsidiary Radiometric Investigations, Conferences, etc.

As the result of inquiries by botanists and agronomists concerning the transmission, reflection, and temperature of growing leaves and methods for determining the same, experiments were made on methods of making temperature measurements with needle-pointed thermocuples of fine (0.05 mm.) wires inserted into the ribs or petiole of a leaf. Data on transmission and reflection have been published in Scientific Paper No. 196, Diffuse Reflecting Power of Various Sub-

stances. The temperature measurements are relative values, which fluctuate very rapidly with every breeze that blows. In quiet air, in the shade, the thick succulent stem of a burdock leaf was 3.5° C. below the room temperature (below the temperature of the water in which it stood) while the leaf was only 0.5° C. below. Similarly leaves of other plants were 0.2° to 0.5° C. below the room temperature. In the sun, however, conditions were different. The cooling by transpiration of water is not rapid enough in comparison to the rate of absorption of solar energy. The temperature of a growing plantain leaf exposed to the sun was 5 to 6° C. higher than the air temperature.

Industrial Applications of Radiometry.

The Bureau is often in a position to assist the manufacturer in solving his own problems, resulting in a great financial saving as well as the improvement of methods and quality of the product. Acting upon the Bureau's suggestion as to the requisite apparatus, a manufacturer of glassware is testing his numerous samples in his search for a glass to be used in the construction of cooking utensils, which has a low reflecting power and hence requires the application of less heat to acquire a given temperature.

Many dyes are used in coloring food products. In connection with the question of detecting artificial coloring in food, advice was given as to the best part of the spectrum to be used in detecting the presence of dyestuffs by the absorption of visible and infra-red rays.

The development of very sensitive radiometric apparatus has brought forth numerous inquiries as to the application of such instruments in measuring small electric currents in telephone circuits, in submarine telegraphy, in phototelephony, for operating relays, reflecting power of concrete (see Scientific Paper No. 196), etc.

Publications on Radiometry.

During the past year the following papers were published, namely, Scientific Paper No. 261, Studies of Instruments for Measuring Radiant Energy in Absolute Value—an Absolute Thermopile; Scientific Paper No. 262, Present Status of the Determination of the Constant of Total Radiation From a Black Body; Scientific Paper No. 279, Distribution of Energy in the Visible Spectrum of an Acetylene Flame; Scientific Paper No. 282, Sensitivity and Magnetic Shielding Tests of a Thomson Galvanometer for the Use in Radiometry; and Scientific Paper No. 284, Constants of Spectral Radiation of a Uniformly Heated Inclosure or So-Called Black Body. II. Scientific Paper No. 287 gives a mathematical discussion of methods of calculating spectral radiation constants.

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.]

Standard Analyzed Samples.

A further and very marked increase is shown in the demand for the Bureau's standard analyzed samples of irons and steels, ores, materials for calorimetry, polarimetry, and oxidemetry, etc. The

number called for during the past year was 2,697 as against 1,826 the year before. A considerable part of the increase is to be attributed to the continuance of the European war. A further part is due to inclusion of the standards for calorimetry and polarimetry, the distribution of which in past years was not under the control of the chemistry division.

No entirely new samples have been added to the list during the year, and but one sample has been renewed. Owing to unforeseen delay in establishing the exact composition of the Alabama iron, referred to in last year's report, this sample is not quite ready to be issued. One sample has been stricken from the list of standards because of inability to obtain from steel makers the material with which to replace the exhausted stock.

The steady and increasing demand for the Bureau's analyzed standard samples, and the importance of adding to their number from time to time in order to meet the calls from industrial and teaching chemists, justifies repeating the requests of past years for a moderate appropriation, to be continued from year to year, with which to maintain and add to the series. This fund should be available for salaries and travel, as well as for the purchase and preparation of materials, apparatus, and appliances. It is believed that an annual appropriation of $4,000 or $5,000 will cover expenses of every kind in connection with these samples.

Platinum Investigation.

The Bureau's knowledge of the character of the platinum ware obtainable in the market has been extended during the year by experiments conducted in the heat division of the Bureau, working in cooperation with the chemistry division. It has been impossible to take up, as yet, the chemical study of the platinum metals and their alloys, to which reference was made in last year's report, but it is hoped to do so during the coming year. Success will depend much upon the active cooperation of the Mint Bureau of the Treasury Department. That Bureau, it is expected, will furnish the material upon which the chemist will work. Already two crucibles made at the New York assay office from metal refined there by different processes have been received for test. The preliminary results of the tests already made seem to indicate that the refiners and mechanical workers of the assay office are in a fair way to provide acceptable ware for the Government laboratories.

Recovery of Gallium and Other Rare Elements from American Spelter.

Through the kindness of representatives of a western producer of spelter (zinc), the Bureau has come into possession of over 50 grams of an alloy, consisting mainly of the rare metal gallium, with the likewise rare metal, indium, as a very subordinate constituent. The production of this alloy results from the present demand for pure spelter, which has made it commercially profitable to redistil the first run of spelter. During the redistillation at a temperature considerably lower than that by which the original spelter was obtained, the included gallium and indium are left, in large measure, in the nonvolatile residue, which consists mainly of lead and iron. From this the gallium-indium alloy is obtained by appropriate treat-

ment. It is hoped, now that larger amounts of gallium seem to be available for study than ever before, that some of its chemical and physical properties can be determined with greater exactness than was done in the past, and also that certain special uses can be found for the metal, which uses, in spite of the rarity and high cost of the metal, will lead to a continued production. A first step, however, is to ascertain the location of the ores of zinc which are richest in gallium. With this end in view, it is hoped to subject a large number of American ores to comparative test by means of the spectroscope, so that these ores may be treated by themselves instead of being smelted with lean ores. The proposed investigation will also take account of the rare metal germanium, which is also a constituent in minute amount of some zinc ores. The optical division of the Bureau has already made a number of spectroscopic tests of ores and products and will continue to cooperate in any further work that may be undertaken.

Tests of American Chemical Glassware and Porcelain.

The difficulty and, indeed, impossibility at present of obtaining chemical glassware and porcelain of high quality from Europe has led several firms in this country to place new products of domestic and foreign make upon the market. Most of these are now undergoing test at the Bureau, in comparison with the best of the older foreign ware. The results, when obtained, will probably be published for the benefit of the public.

Research of the Methods and Standards Employed in Volumetric Analysis.

The pressing need of taking up a thorough study of the methods and standards employed in volumetric analysis has been emphasized in previous reports. It is impossible, however, to attempt this study without additional assistance.

Investigation of Methods of Analyzing Iron and Steel.

During the year a certain amount of investigation of methods of analysis has been carried out in connection with the determination of the composition of certain of the Bureau's standard iron samples, which may be summarized as follows: (1) Study of the effect of size of analysis sample on the percentage of carbon obtained by burning the sample in oxygen; (2) modifying the graphite determination by direct weighing, so as to increase its accuracy and reliability; (3) study of the effect of vanadium on the various methods in use for determining phosphorus; (4) comparison of the Meineke method for sulphur in irons and steels with the somewhat unsatisfactory "oxidation" method commonly used; (5) study of the effect of adding phosphoric acid and of the so-called arsenite end titration in the bismuthate method for manganese; (6) development of a procedure by which titanium can be determined readily, along with chromium and vanadium, in the same analysis portion.

Rapid Electrolytic Determination of Carbon in Steel.

A method has been worked out in the chemistry division, but not yet published, for the rapid estimation of carbon in steel. The method is extremely rapid and seems to be well adapted for control

work in steel plants; at the same time its accuracy is high. The carbon dioxide formed by burning the steel in oxygen is collected in a solution of barium hydroxide of known strength and conductivity. The resultant decrease in conductivity of the solution is a measure of the carbon burned.

Determination of Oxides and Gases in Steel and Iron.

The ability to determine with certainty the oxide and gas content of steel and iron is regarded as of much importance, since the properties of the metals are affected appreciably by such inclusions. The methods for achieving this end are not altogether satisfactory and the Bureau has not been able hitherto, for lack of practical experience with the few methods proposed, to answer inquiries that have been received. Hence, there has been started a study of the subjects in question which will extend probably over a considerable period of time. Already some results have been reached, which have an important bearing on the general problem, but are not of a character to warrant special presentation at this time.

Preparation of Iron-Carbon Alloys.

The work of the past year in the preparation and study of iron-carbon alloys, in cooperation with the metallurgical division, has been confined mainly to the accumulation of a stock of pure electrolytic iron and to the installation of apparatus for large-scale preparation. Samples of pure electrolytic iron have been furnished to a number of investigations within and outside the Bureau for purposes of research.

Ladle Ingot-Test Investigation.

Continuation of last year's work, in cooperation with the metallurgical division, has shown that the lack of chemical uniformity in ladle test ingots was practically in proportion to the physical unsoundness of the ingots, regardless of the shape and size. Accordingly, it is recommended, in continuance of the investigation, that precautions be taken to obtain ingots free from blowholes and other physical unsoundness. The results of the investigation to date and an outline of future work will appear in a technologic paper and in the Year Book of the American Society for Testing Materials, which society has cooperated in the research.

Other Researches on Irons and Steels.

The chemistry division has assisted the metallurgical division of the Bureau in studying the effect of varying temperatures and time of annealing on the breakdown of chilled iron, and by making a preliminary chemical survey of a typical sound-steel ingot.

Determination of Iron.

Continuing an investigation begun five years ago, methods for reducing ferric solutions previous to titrating with potassium permanganate have been compared. The work is still in progress.

Gas Analysis.

All work on problems of gas analysis has been interrupted for a number of months by more urgent matters.

Preparation and Properties of Hydrogen.

Several samples of hydrogen from entirely different sources have been prepared and checked as to purity, with excellent results. Preliminary determinations of the heat of combustion of this pure gas, made by the heat division, have resulted very satisfactorily.

Specific Gravity of Gases.

A number of gas companies have brought to the attention of the Bureau the urgent need for more accurate methods for determining the specific gravity of natural gas, and this problem has therefore been studied for more than eight months. Thousands of dollars per month are in dispute between buyers and sellers where settlements are based upon measurement by the orifice meter because of uncertainty in the specific gravity factor entering into the calculation.

Extended tests made at the Bureau and study of the theory indicate that the commonly employed effusion method can never be made very precise. Accordingly a different principle has been applied in an instrument constructed at the Bureau, with which very excellent results have been obtained. A field test, under supervision of the Bureau, is now in progress with an apparatus of this type, built jointly by a number of gas companies, with the expectation that it will supersede the effusion type if it proves satisfactory. The present indications are most encouraging.

Chemical Work in Connection With Refrigeration Problems.

Work on refrigeration problems, in cooperation with the heat division of the Bureau, has been confined largely to ammonia and has included the testing of several samples for the Bureau plant, the Panama Canal, and for private firms for export certification. The results of the chemical tests will furnish the basis for specifications to be drawn in conference with manufacturers of ammonia.

Several pieces of apparatus for physical testing have been designed and constructed, including a picnometer for density determinations, an electrolytic cell for conductivity measurements at room temperatures, and an apparatus for simultaneously determining differences in freezing points of two samples.

The following chemical tests have been developed and used in connection with the problems of supplying pure ammonia for experimental work: The Bureau's carbide method for the determination of small quantities of water; the combustion method for carbonaceous impurities; and a method for determining the very small quantity of noncondensing gases in relatively pure samples.

Pure ammonia has been supplied to the heat division for the determination of certain physical constants.

The study of gas formation in ammonia refrigeration systems has progressed with the apparatus built at the Bureau to reproduce the conditions present in a compression system. A small compressor will be installed soon to study the problem of partial dissociation of ammonia into hydrogen and nitrogen, which seems to take place at temperatures below 200° C.

A bomb has been built for the study of the behavior of ammonia solutions toward iron. From this may be developed a test as to the suitability of ammonia for use in an absorption plant. The work

on the two absorption machines of the Terminal Power Co. showed the order of magnitude of the amount of gas formed, but owing to the irregularity of the load no relation could be found between the performance of the machine and the amount of gas in the system.

There was presented at the December, 1915, meeting of the American Society of Refrigerating Engineers, through its committee on gas formation, a report on the work done up to that time.

The Critical Solution Temperature and Its Use in the Determination of Moisture.

Considerable work has been done in searching the literature of the above subject. Some experimental work has been done in the hope of applying a method of this type to the determination of water in liquid ammonia.

Proposed Circular on Compressed and Liquefied Gases.

Inquiries received suggest the usefulness of a circular on the compressed and liquefied gases. Much material for such a circular has been collected and a tentative outline prepared. If undertaken, the cooperation of other divisions of the Bureau will be needed.

Proposed Atlas of Equilibria in Nitrogenous Systems.

A work of the character suggested by the title is very much needed in connection with a number of investigations that are under way in the chemistry division.

The object and purpose to be served would be (*a*) to have all bibliographical references in answer to the question: What has been done by other investigators in any particular one, two, and three or more component systems; (*b*) to give the pressure, temperature, and volume (composition) relations in such systems, after a critical survey of the existing data by means of tables or charts.

A start in the realization of the ends sought has been made in connection with certain researches. By making this information part of a larger whole, an instrument of great value to the Bureau, and finally to the scientific public, might be developed. The chief objection to the preparation of such an atlas is the magnitude of the task, in spite of which its certain value makes it very desirable that the Bureau undertake it.

Pure Organic Materials.

Owing to the impossibility at present of obtaining benzoic acid of satisfactory quality, from which to prepare the pure material which the Bureau has issued as a standard for calorimetry and acidimetry, it has been impossible to renew the nearly exhausted stock. The suggestion has not met with the approval of the heat division that the Bureau supply for ordinary calls a material of moderate purity, and reserve what is left of the high-purity supply for special use in investigations that demand the highest accuracy.

A melting oven with gold-plated copper forms for use in the purification of benzoic acid has been constructed. Efforts to secure specially designed sublimators for the purification of benzoic acid, naphthalene, etc., have not been successful.

Conductivity of Electrolytic Standards.

Apparatus for determining the conductivity of electrolytic standards is for the most part assembled and will be used temporarily for work on the conductivity of liquid ammonia as a criterion of its purity.

Chemical Work on the Standard Cell.

The chemical work on the standard cell, in cooperation with the electrical division, is still far from completion, and no results are ready for publication. Nevertheless the accumulated results form a basis for drawing up standard cell specifications that will be good for many years to come. The cells set up have been excellent from the standpoint of constancy and reproducibility. The main work of the past year has been a study of their behavior with variations in the method of washing the free acid from the mercurous sulphate. Acetone has been found to be a very satisfactory substitute for ether, the latter showing some variations owing to the ethyl peroxide formed on exposure to the air.

Considerable work on the purification of acetone and ether has been done in this connection and bearing also on another research.

Investigations Relating to Electrotyping and Electroplating.

The study of electrotyping referred to in last year's report has been continued, and a second edition of Circular No. 52, entirely rewritten and extended, has been published. In this circular, in addition to directions and recommendations for the operation of electrotyping baths, are included a large number of definitions, tables, etc., of value to both electrotypers and electroplaters.

The investigation of copper deposition in electrotyping baths, conducted in part at the Royal Electrotype Co. of Philadelphia and in part at this Bureau, in cooperation with the structural materials division and the metallurgical division, has been practically completed. A preliminary report of the conclusions has been published, and the details are now being assembled for publication as a technologic paper. It is believed that by the application of the conclusions reached in this research uniformly satisfactory results can be obtained with copper electrotyping baths.

The study of the cobalt bath has shown that while this is apparently not applicable for true cobalt electrotypes it may be used to advantage for cobalt-plating copper electrotypes, which operation requires but a very short time and adds to the life of the printing plates when used for black inks. The cobalt-plated electrotypes have not, however, been found suitable for colored inks, so that they will probably not come into commercial use.

Owing to the cutting off of the supply of Galician ozokerite, used in electrotypers' molding wax, efforts are now being made to find satisfactory substitutes. The experiments thus far conducted by the Bureau are only preliminary, but they indicate that by proper adaptation the Utah ozokerite, hitherto considered unsuitable, may be rendered satisfactory for this purpose.

The properties of graphite in relation to their application to this industry and the use of addition agents in copper baths for both electrotyping and electroplating should be investigated. The whole

subject of nickel deposition for electrotyping and electroplating is also in need of investigation.

While no investigations have been conducted by the Bureau from the standpoint of electroplating, the work accomplished in the field of electrotyping has proved useful in some degree to electroplaters. The latter have sent numerous inquiries for information and have offered to cooperate in any work that may be undertaken. The need for research in this direction is great, and any work which this Bureau may accomplish in this field will be a great benefit to an industry in which the possibilities of scientific research are just being realized.

In general, it is very encouraging to note the interest shown by both electrotypers and electroplaters in such scientific investigations as the Bureau is undertaking and planning.

It seems highly desirable that if possible a special appropriation be secured for a study of electrodeposition, including both electroplating and electrotyping. While it is recognized that so comprehensive a subject will require years of study and therefore extend beyond the period for which it may be possible to secure such special funds, the needs and expenses connected with the initiation of such work seems to justify, in fact require, a special appropriation.

Chemical Work on Cement.

In addition to the usual large amount of routine work on cement and cement materials (including also sand, stone, gravel, soils, waters, etc.), three specially prepared samples of cement were carefully analyzed by chemists of the Bureau and a number of others in Government, university, municipal, and private laboratories. This work was done on behalf of the Joint Conference on Uniform Methods of Testing and Standard Specifications for Cement. The analyses were made by the method recommended by the Bureau, and from the results obtained certain limits of accuracy were proposed for use in connection with the acceptance or rejection of material purchased under cement specifications.

An investigation is in progress of the chemical changes occurring in mortar and concrete when exposed to sea water, "alkali" waters, and abnormal conditions.

Nonferrous Alloys and Coated Materials.

In addition to the usual routine work on nonferrous alloys and coated materials, a great deal of analytical work has been done upon samples of tin in connection with an investigation of fusible plugs for the Steamboat-Inspection Service in cooperation with the metallurgical division of the Bureau.

Much analytical work has been done also upon samples of brass cast at the Bureau under varied conditions, with the object of determining if it would be possible to prepare by casting, in ingot form, material suitable for the Bureau's series of standard analyzed samples.

The methods of analyzing certain alloys of lead, tin, and antimony have received much attention.

In connection with the testing of coated metals, members of the Bureau visited a number of plants where galvanized tin and terneplate are made. The information obtained from these visits will be

of value in a joint investigation of these products by the chemistry and metallurgical divisions.

The chemistry division has supervised exposure tests, on the roof of one of the Bureau's buildings, of sheets both low and high in copper, of the ordinary steels, and of ingot and puddled iron. These sheets have been exposed since September, 1915. From the beginning a difference could be observed in the appearance of the high and low copper sheets, the former having a darker and more adherent rust coating. The tests are not sufficiently advanced to permit of further comment.

The chemistry division has analyzed sets of sheet metal furnished by the Post Office Department for exposure on the roofs of a dozen or more post-office buildings in various parts of the country, and will assist in the supervision of the tests and in the tabulation of the results obtained.

Corrosion of Lead Storage-Battery Tanks.

An investigation of lead storage-battery tanks was made for the Navy Department, in which it was shown that the corrosion was due chiefly to acetic acid developed from the wooden strips in conjunction with the carbon dioxide that is normally present. Certain recommendations were made which, it is believed, will prevent or minimize future corrosion.

Investigation of Boiler Water, Boiler Scale, and Boiler Compounds.

It has not been possible yet to take up systematically the contemplated study of boiler waters, boiler scales, and boiler compounds. A laboratory method must first be developed by which water can be evaporated under high pressure, so as to reproduce the conditions and results of actual industrial practice.

Bituminous Materials.

Under bituminous materials are included crude and refined tars, pitches, asphalts, saturated and unsaturated felts and papers, creosoting and dead oils, etc.

Definite methods of tests and specifications have been developed for coal tar, waterproofing, and roofing pitches, to replace the loose and indefinite requirements which have been more or less in use in the Government service. Methods and specifications are being developed also for asphaltic materials. Information is being obtained to insure satisfactory felts and papers for saturation with asphalt and tar products for waterproofing and roofing purposes. Modification of specifications for these latter materials may become necessary, since shortage of rag stock has increased the use of wood pulp, jute, and manila fiber.

A modification has been introduced into the oven that is used for determining the loss in weight of bituminous materials at 180° C. in the shape of a rotating shelf for carrying the samples. By this device variations of temperature in different parts of the oven are made negligible, and concordant results are obtained. This oven has been recommended as standard by committees of the American Society for Testing Materials.

Chemical Tests of Lubricants.

The chemistry division tests lubricating oils and greases in large numbers. In addition to small lots received every few days throughout the year, the Post Office Department and the General Supply Committee each spring transmit large numbers of samples. The data obtained from the examination of these latter oils are studied, and upon the Bureau's recommendation annual contracts are awarded.

A research mentioned in last year's report was completed and published as Technologic Paper No. 73, Data on the Oxidation of Automobile Cylinder Oils. The conclusion was reached that the method used by the Bureau for some four or five years to determine the relative tendencies of oils to "carbonize" is satisfactory. The advantage over other published methods is its comparative rapidity.

Tests along the same lines are regularly made in the laboratory of one of the large refiners of oils. Their chief chemist states that the apparatus in use at the Bureau of Standards is more convenient than that adopted by him.

Quite recently a representative of another firm of refiners, who claim to have the leading oil-testing laboratory in the country, visited the Bureau and saw the oil-carbonizing apparatus. The representative expressed great interest in it and wished to adopt certain of its features. Other work along this general line has been planned.

Some work on the "carbon residue" of oils was done nearly a year ago in cooperation with a section of committee D–2 (on lubricants) of the American Society for Testing Materials. This is entirely distinct from the Bureau's "carbonization" test.

The Bureau is represented on the above committee by one of its chemists. Cooperative work on the emulsification test is planned for the coming year.

Gum Arabic.

In the early years of the Bureau trouble was experienced when examining mucilage in finding a satisfactory test for gum arabic. This is commonly regarded as the best gum used for mucilage. Search of the literature and many trials disclosed two or three satisfactory qualitative tests, and upon one of them was based a new quantitative method for the gum, which appeared as Technologic Paper No. 67, Some Qualitative Tests for Gum Arabic and Its Quantitative Determination.

Paste and Mucilage.

About the usual number of samples of paste and mucilage materials has been tested. The quality of some recent delivery samples of paste has been somewhat below the standard, and some very inferior mucilages have been submitted. The lowering of the quality of the pastes is probably due to the lack of dextrin made from potato starch. The appearance of some of the samples of mucilage was such as to indicate not only inferior raw materials but also gross carelessness in manufacture.

Chemical Analysis of Rubber.

Further progress has been made in the improvement of the methods used in the chemical testing of rubber goods. Considerable attention has been given to the detection and quantitative determination

of the various fillers and adulterants used in rubber goods. Technologic Paper No. 64, The Determination of Barium Carbonate and Barium Sulphate in Vulcanized Rubber Goods, presents a method for determining these two fillers with a considerable degree of accuracy. Attention has been given to the subject of the various oil substitutes, their detection and determination, as well as their effect on the quality of the rubber compounds. Considerable work remains to be done before any satisfactory conclusion can be reached.

The Bureau has continued its cooperation with the Joint Rubber Insulation Committee. The results obtained by this committee during the past year have been so satisfactory that it will issue in the near future a revision of its method of analysis and specification for 30 per cent Hevea rubber insulation. The work of this committee is of value not only to the manufacturers and users of high-grade insulated wire and cable, but to the rubber trade in general. Its procedure of analysis can be used in the chemical testing of many rubber compounds other than insulation.

The method for the determination of total sulphur in rubber, developed at the Bureau, is gradually being recognized as the most satisfactory method known to-day. Private laboratories are using it in their regular work. It seems quite probable that the Joint Rubber Insulation Committee and the American Society for Testing Material will include it in their standard procedures of analysis.

Chemical Specifications for Rubber Goods.

The preparation of standard specifications for rubber goods for use in Government departments and elsewhere constitutes a very important part of the rubber work done at the Bureau. The Bureau cooperates with the Navy Department in the revision of the specifications for rubber goods which it uses and with the Commissioners of the District of Columbia in the preparation of specifications for fire hose. During October, 1915, a conference of representatives from about 20 Government offices was held at the Bureau to consider the preparation of standard specifications and to suggest means whereby the Bureau could be of greater service to these offices in connection with their purchases of rubber goods. The various questions raised at this meeting are being investigated by the Bureau, and it is proposed to hold a second conference during the coming year, to which will be invited representatives of some of the larger consumers, manufacturers, municipal governments, etc.

Sealing Wax.

In response to a suggestion from this Bureau, the Secretary of the Treasury appointed two members of the General Supply Committee to cooperate with a representative of this Bureau in the formation of suitable specifications for sealing wax. A study of the ingredients of sealing wax and the methods of manufacture has been started. A new grade of wax has been placed on the schedule of the General Supply Committee, and the results obtained by the various Government departments who use this wax will be ascertained. The information thus obtained will be used in the preparation of standard specifications and methods of testing. The securing of suitable wax is of considerable importance to several offices of the Treasury Department.

Chemical Properties of Selected Paper Pulps.

A study of the chemical properties of selected paper pulps and of their susceptibility to oxidation and hydrolysis was finished.

A comprehensive investigation of the sizing of paper with rosin has been commenced. In its present state the art is a highly empirical one and there is no standard practice. It is not even known whether the sizing of paper follows the absorption law or whether it is due to a mechanical retention of rosin compounds. The various phases of the size is influenced by its being neutral or not, by the kind of pulp, the temperature, etc.

A study is also being made of the changes that take place in rosin sizing when exposed, in contact with pulps, to the combined action of light and air.

There are many research problems in connection with the manufacture of paper that are now forcing themselves upon the attention of the Bureau. Owing to the nature of the materials involved, much preliminary work must be done and collateral investigations carried on before any given problem can be solved.

Recovery of Paraffin from Paper Scrap.

The Bureau was requested to work out a method for the utilization of waste paraffin paper. Not only the paraffin but also the sulphite pulp stock is valuable. A satisfactory commercial process was devised. Most of the paraffin is separated by steaming the scrap paper in a closed tank and then washing with hot water in a wire drum. The residual paraffin is removed by washing in a beater with hot soap solution and turkey-red oil, followed by treatment with water. A special screen inserted into the beater collects the paraffin, which rises to the top. Three or four rolls of paper were made from the recovered pulp.

Chemistry of Textiles.

Several times during the year the Bureau has been called upon to bring samples of textiles to a bone-dry condition in a specially constructed apparatus. Numerous samples of fabrics have also been tested for permanence of dye and for the presence of size and fillers.

Inks, Typewriter Ribbons, etc.

Many samples of writing and stamp-pad inks have been examined during the year, both as an aid in awarding contracts and to check up deliveries. Owing to the dyestuff situation, there has been a tendency to lower the quality of the ink furnished to the Government departments.

The work of testing typewriter ribbons and carbon papers has been greatly facilitated by the recent purchase of an automatic typewriter.

Numerous samples of printing ink were analyzed during the year by the method worked out at the Bureau and published in Technologic Paper No. 39. Other materials, such as printers' rollers and printing-ink pigments, have also been analyzed.

The Bureau is constantly dealing with problems arising in connection with its routine work on paper, inks of all kinds, typewriter ribbons, textiles, sealing wax, etc. There are also received from time to time miscellaneous samples not readily classified and which have to be carefully studied.

Investigations on Paint and Varnish.

Technologic Paper No. 66 gives a method for the detection of resin in driers, which is reliable except when the resin content is less than 6 per cent of the nonvolatile portion free from ash. The method may be applied to varnish.

A method for the determination of oil and resin in varnish has been worked out at the Bureau which is believed to be more reliable than any previously published method (see Technologic Paper No. 66).

In Technologic Paper No. 76 it is shown that for the determination of volatile thinner in oil varnish any one of a number of proposed methods yields results that are sufficiently accurate for ordinary purposes.

An investigation of the constants of linseed oil mixed in paste form with white lead and zinc indicates that no material changes take place when the pastes are kept in closed cans. The results of this investigation are embodied in Technologic Paper No. 71.

The electrical division of the Bureau is testing an insulating varnish, prepared in the chemistry division after considerable work extended over a period of several months. The varnish is made from tung oil, calcium resinate, cellulose acetate, acetone, and pyridine or other organic base.

Physical-Chemical Problems in Connection with Paint.

There are a number of apparently very important and little understood physical and physical-chemical problems relating to paints which demand investigation by an experienced and able chemist. Among these phenomena may be mentioned apparent great differences in the effects of different liquids on the surface of finely divided solids, such as paint pigments, changes in viscosity or plasticity of paints in keeping, or on addition of substances which are, so far as known, chemically inert.

Paint-Exposure Tests.

The paint-exposure tests, begun over a year ago, are in progress, but several years may elapse before conclusions can be drawn. A record will be kept by means of photographs and inspection of the test panels, which, in three kinds of wood, have been painted with a number of well-known brands of white paints for outside exposure.

Circular on Paint Materials.

A large amount of matter has been prepared for use in a projected circular of information on paint materials.

A chapter on paint, paint oils, and varnishes has been prepared for the projected circular on household materials.

Soap Specifications and Soap Analysis.

Continuing the efforts referred to in last year's report to bring the different branches of the Government service into accord in the matter of specifications for soaps, tentative specifications for white floating, milled toilet, chip, salt water, liquid, and two types of laundry soap were prepared and submitted to a number of manufacturers for criticism. Some of the criticisms and suggestions re-

ceived are now under consideration by experts in the Government service. These specifications, with some general information regarding soaps, will be issued in published form.

A committee of the American Chemical Society is about to take up the study of methods of soap analysis, and in this study the Bureau will cooperate.

Cooperation with the Scientific and Technical Societies.

The Bureau, through its chemistry and other divisions, cooperates actively with various committees of scientific and technical societies.

Reports in which chemists have cooperated are the following: Results of tests of Perilla oil and of raw and boiled linseed oil; revision of the method of standardizing permanganate solutions used in determining manganese in steel by the standard methods of the American Society for Testing Materials; comparison of the above society's standard gravimetric method for sulphur with a method much used in Germany; ladle test investigations; and sampling and analysis of coal.

Exhibit of the Bureau at the First Exposition of the Chemical Industries, New York, September 20–23, 1915.

This Bureau was represented by an exhibit at the First Exposition of the Chemical Industries during September, 1915. The exhibit consisted of wall charts, photographs, publications, apparatus, and samples, so selected and grouped as to illustrate as far as possible the relation of the Bureau's work to specific chemical industries. Among such industires were iron and steel, nonferrous metals, glass and ceramics, lime and plaster, cement and concrete, paint and varnish, ink, paper, textiles, gas, rubber, refrigeration, sugar, bituminous materials, etc., in addition to the electrochemical industries and research laboratories. Every division of the Bureau was represented in connection with one or more industries.

Very great and intelligent interest was shown by the visitors, most of whom were engaged in technical and scientific work. A great many inquiries were made of those in charge of the exhibit, and by letter later, and many hundreds of written requests for specified publications have been received as a direct result of the exhibit.

In general it is believed that the educational value to the public of such exhibits as this far more than repays the Government for the moderate expense and trouble involved in their preparation and maintenance. But the preparation of a truly representative and highly educational exhibit does involve an expense which can not always be and should not be chargeable to the regular appropriations for the Bureau's work.

Correspondence.

A considerable burden of correspondence has to be borne by several chemists. Since the war broke out, and especially during the past 12 months, there has been a greatly increased number of letters asking for information about different branches of chemical manufacture and technology. Many of these have been answered by referring the writers to readily accessible books which give the desired information in greater detail than would be possible in a letter. Often a long

reply, requiring extensive search through the chemical literature, is prepared.

The Bureau has been asked in numerous letters to give detailed descriptions of the methods of manufacture of various products of commercial importance. These requests have come from individuals, firms, and even civic organizations. In many cases it has been all too evident that the letters have been written by persons having no chemical training or knowledge, who wished to establish a new industry. The writers have been given the desired information whenever possible, but with the warning that even the least complicated chemical industry requires trained supervision.

Chemical Testing.

The routine testing of the chemistry division shows a decrease, which is due in large part to the decreasing amount of work for the Panama Canal and to the efforts on the part of the Bureau to eliminate useless tests.

More than 10,600 such tests of materials were made in the chemical laboratories during the year. They involved the following materials: Ferrous metals (irons and steels), 437; coated metals, 378; nonferrous metals and alloys, 809; material from electrotyping baths, 27; cement materials, 1,121; coal tars, asphalts, and saturated felts, 1,044; burlap and building paper, 127; linseed oil, turpentine, and driers, 761; varnish and shellac, 520; red lead, white lead, putty, 508; graphite paint and miscellaneous paint colors, 697; greases, 77; soaps, 366; nondrying oils, metal polishes, 178; lubricating oils, 546; inks and ink materials, 165; flax packing, 29; asbestos, 62; paper, 1,964; rubber, 230; sealing wax, 16; textile materials, 150; miscellaneous, 457.

The above tests were made for about 70 Government bureaus and establishments, including practically every executive department, as follows: Agriculture, 32; Commerce, 1,349; Interior, 183; Labor, 31; Navy, 214; Post Office, 541; Treasury, 3,550; War, 222; United States committees and commissions, 15; General Supply Committee, 326; Government Printing Office, 1,460; the Panama Canal, 2,306; other independent Government establishments, 28; State, municipal, and other institutions and committees, 313; private parties, 99.

Miscellaneous Chemical Tests, Researches, Specifications, etc.

In addition to the large number of routine chemical tests made during the past year, there have been occasions when the tests were of a more extended nature and semi-investigative in character. These tests involved such problems as the following:

(1) An analysis was made of Jena boro-silicate glass for the information of the ceramics division at Pittsburgh.

(2) A material supposed to be amber and said to occur in quantity near the Panama Canal Zone was shown to be perhaps a variety of gum copal.

(3) Suggestions were made to the Bureau of Construction and Repair, Navy Department, as to specifications for alcohol.

(4) Upon request a specification for red lead in oil was prepared for use in the Panama Canal Zone.

(5) Following a suggestion of the chemistry division, based upon protests made to the Steamboat-Inspection Service by shippers

against the exclusion of certain oils from passenger vessels, the solicitor has ruled that all oils, whether petroleum or not, which show a fire test of not less than 300° F. will be permitted as stores on passenger vessels.

(6) On account of the almost universal custom of using potassium hydroxide in determining the saponification numbers of ordinary oils and fats, and the abnormal shortage in all potassium compounds, it is desirable to substitute the cheaper sodium hydroxide, if such substitution is allowable. Tests made in the chemistry division show that the cheaper compound is entirely suitable for the purpose mentioned. It can replace the potassium compound, without doubt, in many other operations.

(7) Trouble having been experienced in removing the silver coating from Wollaston platinum wire by the treatment usually recommended, several solvents less energetic than nitric acid were tried. Potassium cyanide removes the silver satisfactorily.

(8) A certain brand of photographic flash powder was tested for the Steamboat-Inspection Service and found to be at least as safe as black gunpowder, which is permitted on passenger vessels.

(9) Thermit, although it produces a most intense heat while burning, could not be ignited by any ordinary means, and on the recommendation of the Bureau is permitted as freight on passenger vessels.

(10) A container for liquid hydrogen sulphide has been constructed and filled. A small leak developed, which defect it is hoped to overcome by certain mechanical alterations.

(11) The matter given off by cottonseed oil under very much reduced pressure was found to consist of a small amount of dissolved gas and volatile organic matter, together with a very much larger quantity of water. Further experiments are contemplated to show the relation of this material to the quality of the oil. Evacuation was found to improve the flavor and odor of the oil.

(12) Some work, still in progress, has been done on the determination of reducing matter extracted from high-grade filter paper.

Publications.

The following papers and circulars emanating from the chemistry division have been published during the year or are nearly ready for publication: Standard Methods of Sampling and Analysis and Standard Samples (presented before the Second Pan-American Scientific Congress and published in part in the Journal of Industrial and Engineering Chemistry, vol. 8, p. 466); Recovery of Gallium from Spelter in the United States (published in the Journal of Industrial and Engineering Chemistry, vol. 8, p. 225); Technologic Paper No. 73, Oxidation of Automobile Cylinder Oils; Technologic Paper No. 67, Some Qualitative Tests for Gum Arabic and its Quantitative Determination; Technologic Paper No. 69, The Determination of Carbon in Steels and Irons by Direct Combustion in Oxygen at High Temperatures; Rapid Electrolytic Carbon Determinations in Steel and Iron (not yet published); second edition of Circular No. 52, Regulation of Electrotyping Solutions (entirely rewritten and extended); Scientific Paper No. 286, The Determination of Aluminium as Oxide; second edition of Circular No. 48, Standard Methods of Gas Testing (revised and

extended); The Substitution of Heating Value for Candlepower as a Standard for Gas Quality (presented before the International Gas Congress, 1915); Technologic Paper No. 64, The Determination of Barium Carbonate and Barium Sulphate in Vulcanized Rubber Goods; Technologic Paper No. 76, The Determination of Volatile Thinner in Oil Varnish; Technologic Paper No. 71, The Effect of Certain Pigments on Linseed Oil; Technologic Paper No. 66, The Determination of Resin in Drier; Technologic Paper No. 267, The Colorimetric Determination of Acetylene and Its Application to the Determination of Water; and Scientific Paper No. 275, Relation Between the Composition and Density of Solutions of Copper Sulphate and Sulphuric Acid.

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 test, 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 aeroplane parts and materials, etc.]

Water-Current Meter Rating Station.

The station for rating of current meters, consisting of a reinforced concrete tank 400 feet long, 6 feet wide, and 6 feet deep, and an electrically driven carriage for supporting the meters under test and the recording apparatus, has been entirely housed in by a frame structure during the past year. The work of the station can now be carried on without interruption at all seasons of the year, in winter as well as in summer. Instruments submitted can now be tested and returned to their owners with a promptness which has not heretofore been possible. Engineers outside of the Government service have been availing themselves to an increasing degree of the Bureau's facilities for testing these instruments. During the past fiscal year 41 such ratings were made. As a part of a more comprehensive investigation, a number of tests have been made at the station to determine the effect of different methods of cable suspension commonly employed in field use upon the action of the small Price current meter and the variation from the standard rating caused thereby.

Radiator Traps Used in Vacuum Systems of Heating.

The testing of different makes of radiator return line valves used in vacuum heating systems, begun at the request of the Office of Supervising Architect of the Treasury Department during the last fiscal year, has been continued and extended at the request of that office. A new testing apparatus has been constructed, affording facilities for testing these valves both when applied to radiators of the steam and of the hot-water type. Reports have been made of the results of a large number of tests of these devices. New makes of valves are still being submitted, as well as valves which have been redesigned to correct defects disclosed by these tests. Great interest in this investigation has been shown by the manufacturers of these devices, many of whom have visited the Bureau for a day or two to witness tests. The data obtained furnishes not only a comparison of

the degree of success with which these valves operate, but will also serve as a standard of performance for specifications covering the operation of such devices.

Fire Extinguishers.

At the request of the Steamboat-Inspection Service, an investigation of first-aid fire appliances for use on vessels has been in progress at this Bureau. Over 60 different makes of devices of this character have been assembled for the purpose of studying the advantages and defects of different types of apparatus now available for this service.

Gasoline-Engine Testing Laboratory.

There has recently been installed at the Bureau a 6-cylinder automobile engine with which it is proposed to test the efficiency of materials that are being marketed with the claim that when added in small quantities to gasoline an increased efficiency is secured, together with freedom from carbonization.

In conducting this investigation, an electric absorption dynamometer will be used to measure the power developed, and to determine the relative efficiency of the engine when using straight gasoline as compared with its efficiency when using gasoline containing the various materials being investigated.

Anemometers as Speed Indicators for Aeroplanes.

A report on anemometers as speed indicators for aeroplanes, which had been prepared by the Bureau at the request of the Langley Aerodynamical Laboratory, was published during the past year in the first annual report of the National Advisory Committee on Aeronautics. This report deals with the various types of anemometers, including Pitot tubes.

High-Pressure Gauges.

During the last several months 10 industrial establishments and manufacturers of gauges have requested the Bureau to calibrate high-pressure gauges. The gauges tested were designed for maximum pressures varying from 1,000 to 20,000 pounds per square inch.

Test of Speedometers.

The Office of Public Buildings and Grounds made use of the special equipment of the Bureau during the past year for the purpose of having tested for accuracy the speedometers used in the patrolling of the public parks of Washington.

Tests of Miscellaneous Instruments and Devices.

In addition to the rating of current meters, 258 of which were tested during the past year, 145 tests were made of miscellaneous engineering instruments and devices, including steam, vacuum, and hydraulic gauges, anemometers, speedometers, indicator springs, paper testers, vacuum cleaners, fire extinguishers, and valves. These tests were made at the request of various Government departments, manufacturers, and individuals.

7. METALLURGY.

[Thermal analysis and structure of metals, heat treatment and its effect upon the properties of metals and alloys, including the researches involved in determining the causes of metal failures, cooling and heating curves; the investigation of hardening, annealing, tempering, cementation; the determination of critical ranges; and the preparation of pure metals and alloys.]

Quality and Volatilization of Platinum.

The platinum situation has been especially acute during the past year, and the scarcity of this metal has rendered imperative the development of all possible sources of supply for use in chemical and physical operations in which high-grade metal is desired. To that end the Bureau has been cooperating with the Bureau of the Mint with a view to refining and testing the platinum there produced. Also, there has been made and published an investigation of the effect of various impurities on the loss of weight by volatilization, over the temperature range 700° to 1,200° C., of platinum crucibles of several degrees of purity. Data have been accumulated which permit of satisfactory specifications being drawn for platinum utensils.

The results of this investigation may be summarized briefly as follows: All platinum carries iron as impurity, which, diffusing to the surface and oxidizing on heating, tends to increase the crucible weight and mask the volatilization losses. These losses for platinum nearly free from iron, expressed in mg/100 cm²/hour at the temperatures indicated, are shown below:

Platinum containing—	Pure platinum.	1 per cent iridium.	2.5 per cent iridium.	8 per cent rhodium.
900° C. or less	0	0	0	0
1,000	0.08	0.3	0.57	0.07
1,200	0.81	1.2	2.5	0.54

Platinum crucibles should be made, therefore, free from iron and iridium, and should contain a small percentage of rhodium. Further investigations may possibly demonstrate the superiority of platinum crucibles alloyed with osmium.

Failure of Structural Brass.

An investigation has been concluded of the initial stresses, cause of failure, and properties of structural brasses, an account of which is to be published as a technologic paper. This investigation has shown that many failures of wrought brass bolt, rod, sheet, etc., have occurred as a result of the presence of severe initial stresses in the materials, the maximum values of which frequently exceed the average yield point of the material. Methods are described for the measurement of such stresses and correlation is made between the physical properties and the values of such stresses. A thorough microscopic study was also made of the structure of such materials in the effort to relate it to the occurrence of failures of these materials. It has been shown that failure of wrought brass materials may be due to initial stress, overstress due to service load, or to im-

proper forging treatment. Failures of the first class can be eliminated by annealing the material at low temperatures, 300° C.

This investigation is part of a general one into the causes of failure of 60:40 brasses, which has taken a number of directions. A great deal of this work has been materially aided by the cooperation of brass manufacturers and of users of brass, such as the Navy Department, the New York Board of Water Supply, the city of Minneapolis, the Panama Canal, etc., and a great deal of work has been done which, owing to its isolated character, tests, etc., may never be published. It is expected that the results obtained here will be serviceable in framing specifications for the use of structural brass.

Stresses in Brass Caused by "Burning-in."

In connection with the cracking of some of the mammoth cast manganese bronze valves of the Catskill Aqueduct an investigation has been made of the initial stresses introduced by the "burning-in" of this material. It has been found that it is readily possible to thus introduce stresses equal in value to the "true" elastic limit of the material, thus casting much doubt upon the advisability of such procedure in cases where annealing can not afterwards be resorted to. An account of this investigation is in press.

Corrosion of Brass Under Tension.

A study has been made of the effect of a tensional stress upon the electrolytic electromotive force of brass, and hence upon its corrodibility. It has been found that there is a slight increase in electromotive force as the stress is increased, and this fact is made the basis of an explanation of Mr. Jonson's experiments (of the New York water board), and of the general phenomenon, noted in brass, of failure under lower stresses when corroding than when not being corroded.

Expansion of Constituents of Brass.

A study has been undertaken of the coefficients of expansion of the constituents of 60:40 brass (and similar complex brasses), as leading toward a better understanding of the initial stress conditions which may develop as a result of widely differing coefficients of the two constituents during the cooling of this heterogeneous alloy. So far measurement has shown that the beta constituent of 60:40 brass has a much greater coefficient than that for alpha. As an alloy containing both constituents cools, the beta contracts more and is left in tension in the cold alloy. Much work remains to be done on both the experimental and interpretive side of this problem; it is, however, a phase of metallurgical investigation which as yet has been untouched and promises interesting results.

Corrosion in Water of Stressed Brass.

The behavior under tensional stress of 60:40 brass, particularly manganese bronze, is being studied to determine the effects of corrosion in water over long periods of time. This study will supplement the work of Mr. Jonson, of the New York water board, in his acceleration tests with ammonia, and should give definite data as to the upper safe stress limit for such material. Twelve stress frames have been made for this purpose and a start has been made on the problem.

Impurities in Brass Affecting Its Properties.

The question has been raised, with respect to possible interpretation of some of the failures of wrought brass (of Catskill Aqueduct material), of the effect on the properties of the finished metal of minute quantities of certain impurities such as cadmium. A preliminary study of the influence of cadmium in as minute quantities as 0.01 to 0.05 per cent was made and an exact and fairly rapid method of analysis developed. The results thus far obtained are rather indeterminate, although there appeared to be an indication of correlation between cadmium content and brass failures, considered statistically.

Determination of Carbon in Steels at High Temperatures.

A study of the determination of carbon in steels at high temperatures has been made, and the results of this work show that combustions made in oxygen at temperatures above the fusing points of the iron oxides formed during combustion yield results only slightly higher (averaging 0.015 per cent) than those given by the direct-combustion method as usually practiced. The ordinary methods may, therefore, be considered satisfactory, except where extreme accuracy is desired in the estimation of carbon in steel.

Preparation of Pure Iron.

The furnace facilities and accessories have been increased during the past year, thus permitting the preparation in vacuo of ingots about 6 by 2 inches of pure iron free from gases and other inclusions or impurities from metal deposited electrolytically at the Bureau. The product is probably the purest iron in existence, and the Bureau has had many calls from scientific investigators for samples, which have gone to several university and other scientific laboratories in the United States, Japan, and Great Britain. This material will also be valuable for use in determining physical properties at the Bureau, as a spectroscopic standard, and as a basic metal for making up a series of alloys or steels of exactly known and desired chemical composition free from the impurities usually present in steel.

Tin Fusible Boiler Plugs.

The Steamboat-Inspection Service has called on the Bureau for additional investigation of several problems relating to the manufacture, composition, testing, and specifications of tin fusible boiler plugs, which are used as safety devices in marine boilers. Some of the manufacturers have had considerable difficulty in meeting the necessarily rigid requirements. The principal difficulty has been traced to improper methods of filling the casings and the use of brass instead of bronze casings. The Bureau has been able to make suggestions which should obviate the difficulties met with. It has been found that the tin filling will become contaminated with copper and zinc from the casing if filled too hot. In view of the fact that the presence of zinc in the tin filling will cause the plug to deteriorate, as shown by the Bureau, the casing should preferably be made of bronze. The Bureau has offered suggestions to the Steamboat-Inspection Service as to the modification of its specifications for such plugs.

Allotropy of Copper.

Several Dutch physicists had concluded from their investigations that there were one and perhaps two allotropic changes in copper at about 70° C. and 110° C. Experiments made here by an electrical resistance method failed to show any evidences of discontinuity in properties, to at least 1 part in 50,000. This matter is also of considerable practical importance as the existence of the possibility of instability at ordinary temperatures in such a widely used metal as copper might have far-reaching effects in instruments of precision and in electrical apparatus and equipment.

Thermoelectric Properties of Iron.

A further contribution to the knowledge of the properties of pure iron has been made and is nearly ready for publication, consisting in a determination of the law of variation of the thermoelectric power of the couple iron-platinum with temperature to 1,000° C., by a new method which eliminates the uncertainties and ambiguities usually present in measurements of this kind. The thermoelectric characteristics of the critical points (A_2 at 768° C. and A_3 at about 910° C.) of pure iron are demonstrated. At A_3 there is an abrupt discontinuity of large magnitude, while at A_2 there is a change in direction only of the curve representing thermoelectric power. These results have considerable bearing in the interpretation of the type of transformation at A_2 and A_3.

Segregation in Steel Test Ladle Ingots.

This investigation, carried out in cooperation with a committee of the American Society for Testing Materials and several steel manufacturers, has been sufficiently advanced to warrant a preliminary publication in the form of a report to the American Society for Testing Materials. The results obtained thus far relate to a chemical and metallographic survey of typical test ingots (on which chemical analysis the sale of the product is based), such as used in the widely divergent practice in American steel mills. A less marked effect of the shape and size of test ingot, as influencing a heat analysis, was found than was expected. The question of the soundness of the test ingot appears to be of first importance. This investigation will be continued by examining four types of ingot poured at the same mill from steel of different compositions and metallurgical condition ("rising," "killed"), and the effect of adding deoxidizers such as aluminum to the test ingot will be studied.

Iron-Carbon Equilibrium.

Although some progress has been made in the study of iron-carbon equilibrium, advance in this investigation of fundamental importance has been greatly retarded and then suspended for the present, due to the absence of some nine months and final resignation of one of the staff engaged in this work. It is hoped to be able to push this investigation to a successful conclusion during the coming year, and to accompany it with a metallographic study of the iron-carbon transformations.

Metallurgical Examination of Failed Railway Material.

The several lines of investigation in this subject were outlined at some length in last year's report and progress has been made in all the items mentioned, including (1) an exhaustive study of the type of failure known as "transverse fissure" in rails, in which several divisions of the Bureau and the railroads of the country are cooperating; (2) an examination of the soundness and other characteristics of steel ingots of several methods of manufacture and their suitability for use in the manufacture of railway material, such as rails, wheels, and tires, and in which the Bureau has the cooperation of several steel companies; (3) a cooperative investigation with the Pennsylvania Railroad of rails made from several types of ingots; (4) the determination of the internal heat stresses in car wheels caused by braking; (5) the heat treatment of locomotive and helical car springs; (6) the relation of combined carbon to annealing time for cast irons of car-wheel type in the course of which improvements in analytical methods have been made; (7) the temperature distribution over rail sections while cooling; and (8) the publication (see Technologic Paper No. 61) of Some Foreign Specifications for Railway Material: Rails, Wheels, Axles, Tires, including a summary of accident statistics. The work on ingots, wheels, and rails will be continued during the coming year. It is hoped to be able to take up some work on the heat treatment of axles, as well as the effect of certain constituents, such as sulphur and manganese, on the properties of chilled cast-iron car wheels, and a metallographic study of the metal in the tread of such wheels to endeavor to correlate this with characteristic failures. A study of the surface defects in rails with reference to their failure is also desirable. The equipment for this railway work is necessarily, for the most part, heavy and expensive and can only be accumulated slowly with the present appropriation available.

Melting Points of Refractory Metals, Oxides, and Steels.

Some further progress has been made, especially in the location of the melting points of the refractory chemical elements. It has been found necessary to improve the apparatus for use with certain metals which can be melted without undergoing change only in a high vacuum.

Deterioration of Tinned Copper Roofing.

An investigation is being made of the metallographic structure and properties, particularly the electrolytic electromotive force of the tin coating on tinned sheet copper. This was taken up, at the instance of the Librarian of Congress, where there is an interesting case of extreme local corrosion.

Protective Metallic Coatings on Metals.

The Bureau has had a considerable amount of testing to do, mainly for the Government departments, of plated or coated metals, especially galvanized iron. A systematic study of the manufacturing limitations and properties of this class of material was considered desirable and has been begun; and together with a committee of the

American Society for Testing Materials, the experimental data and experience are being accumulated for forming specifications for galvanized materials, including sheets, wire, and pipe.

Properties of Electrolytically Deposited Copper.

During the year an investigation of the conditions, physical and chemical, surrounding the electrolytic deposition of copper was undertaken in cooperation with the chemical and structural materials divisions. The problem, usually considered from the electrochemical standpoint only, probably has its greatest significance in the physical and metallographic properties of the deposited metal as influenced by the physical factors, as current density, determining the condition of deposition. This study should be extended to other metals, such as nickel, silver, etc. (See pp. 31–v and 6–vii–1.)

Corrosion of Muntz Metal (60:40 Brass).

The Bureau has had brought to its attention during the past year several striking and typical cases of the deterioration of Muntz metal by selective corrosion; and using this material as a basis, a study has been made of this class of failure, the results of which are in press. The general characteristics of this type of corrosion, the eating out of the zinc from the brass, are well known, but there are still several outstanding puzzling factors related in part to the conditions of manufacture and in part to the actual mechanism of the corrosion.

Crystalline Changes in Wrought Iron Under Stress.

A failed bridge member sent by a railroad to the Bureau for test showed a very interesting case of changed crystalline structure in wrought iron, with high phosphorus content, brought about by overstressing the material. As there appears to be considerable misunderstanding regarding the relation of "recrystallization" to metal failure, the metallographic results of this test are embodied in a forthcoming technologic paper.

Investigations in Metallurgical Chemistry.

Several of the investigations in progress in metallurgical chemistry are described at length in the report of the chemistry division. These include a method for rapid electrolytic determination of carbon in steel; an investigation of methods for determining oxides and gases in steel and iron, undertaken in connection with the railway material investigation; and revisions of certain methods for several constituents in steel analysis, in connection with a committee of the American Society for Testing Materials.

There is planned a study of deoxidizers for steel and iron, including a comparison with iron and steel produced in vacuo. It is probable, for example, that the remarkable magnetic properties of the vacuum-produced metal are related to its freedom from one or more gases. This work will be carried on parallel with the study of gases and oxides in steel.

Foundry Problems.

The brass foundry has proved an indispensable adjunct to the metallurgical work directly, and has been found extremely useful by practically all the other divisions of the bureau for the preparation of ordinary brasses and bronzes and particularly of special alloys and castings for research, testing, and instrument parts.

Among the problems belonging to the foundry proper may be mentioned the comparison of the castings of Government bronze (88 Cu—10 Sn—2 Zn) made at five foundries from the same ingot metal with a view to defining specifications of this material. This work is nearing completion.

Members of the art commissions of the cities of New York, Philadelphia, and Detroit, as well as certain art-bronze manufacturers, have urged the Bureau to take up the question of the standardization of art bronzes for outdoor statuary. This should include a determination of the most suitable chemical composition, the production of a desirable and agreeable patina, and methods of care and cleaning such statues. In the different cities of the country statues oftentimes take on an unsightly appearance, largely caused by the contaminated atmosphere. It is believed a systematic study will go far toward improving this condition.

Another matter in which a beginning has been made is the problem of deoxidizers for bronzes and brasses. The obtaining of these metals in an entirely deoxidized condition is recognized as of great importance where strength, impermeability, and uniformity of properties are desired, particularly in castings; and probably also the effect of the presence of included oxides on corrosion is considerable.

A committee of the American Foundrymen's Association met at the Bureau and discussed several problems, solutions for which are desired by the foundrymen. A strong desire was expressed for the standardization of molding sand and definitions of satisfactory tests for this material. The Bureau has therefore undertaken some preliminary work along these lines.

Temperature Measurements in Open-Hearth Steel Practice.

It is recognized to be of fundamental importance in the manufacture of steel to have suitable control and satisfactory methods of measurement of the temperature of the several operations involved. As opportunity has offered, there has been made by the Bureau during the past few years a series of measurements of furnace and pouring temperatures in several steel plants, which go far to demonstrate the practicability of a pyrometric control of the operations of the open-hearth furnace. It is expected to be able to publish these data shortly.

Pyrometric Standards.

Pure zinc, aluminum, and copper have been prepared, through the courtesy and collaboration of producers of these metals, of the highest possible purity for use as pyrometric standards by means of their melting points, and arrangements made for securing pure tin. All these metals are of American manufacture. The metallurgical, heat, and chemical divisions of the Bureau are cooperating in this work.

Cheaper Metal Substitutes.

The past year has witnessed an abnormal rise in price of several of the more commonly used metals, and in consequence the Bureau has received numerous requests for advice and suggestions looking to the substitution of cheaper metals or alloys for various purposes. This opens up a very interesting field of investigation, as it would appear that the metals actually used are oftentimes not better adapted for the purpose intended, especially in certain manufactured products, than others, a slight change in price being sufficient to warrant a substitution. One can not offhand, however, usually suggest such substitutes, as there are many factors involving manufacturing peculiarities, durability, and other physical and chemical properties which have first to be determined. There is a very wide field for research here which would undoubtedly repay many fold the efforts put upon it. Some of the questions of this kind which have been put to the Bureau are substitutes for zinc, copper, and antimony for several manufactured products and in certain alloys.

Cooperative Work in Metals.

Emphasis should again be placed on the beneficial results that have accrued to all concerned from the policy, which has been adopted by the Bureau in the solution of many of its problems, of cooperating with the committees of scientific and technical societies on the one hand and with manufacturers and users of material on the other hand. The past year there have been held two meetings at the Bureau of the very active advisory committee on nonferrous metals; a new advisory committee was instituted by the American Foundrymen's Association, who are interested in molding sands, cast and malleable iron, and other foundry problems; and the work with committees of the American Society for Testing Materials has been considerable. A conference on standardization of sieves was also held. As mentioned in the descriptions of the investigations under way, the execution of several of them would have been impossible without the cooperation of manufacturers, railroads, public bodies, or others interested.

Activity in Technical and Scientific Societies.

The results of the Bureau's work in metallurgy have been presented in papers or discussion before the following societies: American Chemical Society, American Electrochemical Society, American Physical Society, American Institute of Metals, American Foundrymen's Association, American Institute of Mining Engineers, American Society for Testing Materials, Faraday Society, and Iron and Steel Institute of Great Britain.

Information Furnished on Metallurgical Subjects.

The volume and scope of the correspondence of the metallurgical division is growing very rapidly and occupies a large portion of the time of the small staff available for this purpose. This correspondence is mainly concerning the preparation, properties, and uses of metals and alloys and frequently requires elaborate bibliographical research. The Bureau oftentimes profits, however, by having called to its attention gaps in the knowledge concerning metals that should

be filled by further research. The magnitude of this aspect of the work is represented by some 250 requests, each on a different subject concerning metals, for information of this character, to which separate and detailed replies were sent.

There also visited the Bureau to discuss metallurgical subjects and inspect our methods of investigating and testing metals a great many technical and scientific men, including several score from foreign countries, including technical representatives of several Governments.

Circulars of Information on Metals.

The Bureau proposes to issue from time to time, as may be possible with the limited staff available for this purpose and as there may be demand for them, circulars of information concerning some of the more interesting and important classes of metals and alloys.

During the past year there has appeared, as the first of this series, a circular (No. 58) on Invar and Related Nickel Steels, which has been well received. There is in preparation one on the widely used alloy known as Government bronze, 88 Cu—10 Sn—2 Zn, and one on metals for pyrometric standards.

Metallurgical Tests.

A summary of the metallurgical tests is given below; their total value in fees is $3,129.50. Of these test items, 88 per cent were for the various departments of the Government and 12 per cent for private individuals and corporations. Many of these tests were of a very important nature, involving considerable investigation and special installations, and some have served as starting points for special experimental research.

Name.	Heat treatment and thermal analysis.		Metallographic.			Fusible plugs.	Brass and bronze failure.	Miscellaneous.	Grand total.
	Irons and steels.	Non-ferrous metals.	Identification of metal and process of manufacture.	Metal failures.	Miscellaneous.				
For the Government:									
Bureau of Standards	55	1			8			32	96
The Panama Canal	10		190			4	4		208
Steamboat - Inspection Service					1	446			447
Miscellaneous	3		7	7	6	4		2	29
Total	68	1	197	7	15	454	4	34	780
For the public	5	6	3	4	30		47	11	106
Grand total	73	7	200	11	45	454	51	45	886

In addition, the foundry has produced 1,084 ordinary bronze and brass castings representing some 600 patterns, besides a considerable number of castings of special alloys for various investigations, and melting into ingots of some 2,450 kegs of metal.

Metallurgical Publications.

The following metallurgical publications have been issued by the Bureau during the year, many of them being reproduced in American and foreign technical journals: Scientific Paper No. 250, Characteristics of Radiation Pyrometers; Scientific Paper No. 254, A Study of the Quality of Platinum Ware; Scientific Paper No. 280, Further Experiments on the Volatilization of Platinum; Technologic Paper No. 59, Standard Test Specimens of Zinc Bronze (88 Cu — 10 Sn — 2 Zn); Scientific Paper No. 266, Preparation of Pure Iron and Iron-Carbon Alloys; Technologic Paper No. 53, An Investigation of Fusible Tin Boiler Plugs; Technologic Paper No. 60, Microstructural Changes Accompanying the Annealing of Cast Bronze; Technologic Paper No. 61, Some Foreign Specifications for Railway Materials; Technologic Paper No. 69, Determination of Carbon in Steels and Irons by Direct Combustion in Oxygen at High Temperatures; Circular No. 58, Invar and Related Nickel Steels; On a Supposed Allotropy of Copper, published in the Journal of the Washington Academy, *5*, p. 657, 1915; A Test of a Surface Combustion Furnace, published in the Journal of Industrial and Engineering Chemistry, *8*, p. 361, 1916; Segregation in Steel Test Ladle Ingots, published in the Proceedings of the American Society for Testing Materials, June, 1916; Preliminary Report on Testing of Molding Sand, published in Transactions of American Foundrymen's Association, *24*, p. 143, 1916; The Failure of Structural Brass, published in Transactions of the American Institute of Metals, 1915; Magnetic Studies of Mechanical Deformation in Certain Ferromagnetic Metals and Alloys, published in Transactions of the American Institute of Mining Engineers, p. 2371, 1915; Thermometry, Pyrometry, and Heat Conductivity, published in Standard Handbook for Electrical Engineers. Other papers in press or in course of preparation are: Observations on the Crystalline Changes Occurring in Wrought Iron Under Stress; Deterioration of Muntz Metal (60:40 Brass) by Selective Corrosion; The Occurrence and Significance of Twinned Crystals in Electrolytic Copper; Deposition of Copper in Commercial Electrotype Baths; Initial Stresses Produced by "Burning-In" of Manganese Bronze; Comparison of Zinc Bronze (88 Cu — 10 Sn — 2 Zn) for Five Foundries; Corrosion of Tinned Copper Roofing; Initial Stresses and Microstructure of Wrought Brass; The Effect of Corrosion in the Ductility and Strength of Brass; Thermoelectric Measurement of Critical Points of Iron; Temperature Measurements in Open Hearth Practice.

8. STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

[Strength, hardness, elasticity, plasticity, permeability, composition, structure, and other physical and chemical properties of structural and miscellaneous materials, such as cement, stone, clay, lime, paper, textiles, rubber, etc., including laboratory and field work in developing methods of test, standards of quality, and the relation of quality to the efficient utilization of such materials.]

Investigation on Structural Steel Columns.

An important investigation, which has been in progress for a number of years and which is of value to the engineering and architectural professions, consists of two series of column tests which the

Bureau is making in cooperation with the steel column committee of the American Society of Civil Engineers and the steel column committee of the American Railway Engineering Association.

The series of columns recommended by the American Society of Civil Engineers originally comprised nine different types of cross section. Each type was represented by what was called a light section and a heavy section, and in both the light and the heavy section of each type there were three columns of each of three different lengths.

The American Railway Engineering Association columns originally comprised 18 latticed columns with rectangular bearing plates at both ends. As in the American Society of Civil Engineers' series, both light and heavy sections, each with three different lengths, were tested, three columns for each length.

Tests upon these two original series have been completed. A considerable addition has been made to the original American Society of Civil Engineers' program. In order to obtain a relation, if possible, between the ultimate strength and the slenderness ratio, additional columns, totaling 36, have been selected having such areas, cross sections, and lengths that the slenderness ratio will be different from those embraced in the original series; that is to say, tests upon the columns proper covering a range of $\frac{l}{r}$ (slenderness ratio) from 20 to 155 will, when completed, have been made.

Twenty-four columns have been added to the series of the American Railway Engineering Association. The columns are of the same type as those of the original series, but modified in some single detail for the purpose of determining the effect of such modification on the strength of the columns.

The purpose of these tests is to determine the best form of cross section of columns and also to correct or confirm the formulas used by engineers and architects for calculating the strength of columns. Not alone are such formulas valuable for determining the loads which can safely be carried by the columns used in various structures, but they also enable the designer of columns to make the most economical use of the steel employed in their construction.

During the past year 77 columns have been tested. In addition a large number of tests, approximately 40, have been made on short-length struts, tested both as built-up sections, with the same cross sections as in the main column schedule, and also tested as individual units. The program of application of loads upon these short-length test specimens is the same as that of the columns. Tests have also been made upon test specimens cut from the column material and tested in tension, using the same loading program as that used in testing the columns. A comparative study of the results so far obtained from these tests has not yet been made; valuable data, however, are being obtained.

The investigation upon columns will be augmented by the addition of about 250 columns which have been in the possession of the Watertown Arsenal and which will be transferred to the Bureau.

Investigation of Railway Materials.

Investigation as to the causes of failure of rails and other railway materials and of their properties has been continued during the past

year. A detailed investigation is being made of rails containing the so-called "transverse fissure," with the endeavor to ascertain under what conditions this type of failure is produced. Railway companies in different sections of the country are assisting in this investigation and have furnished, as a part of their cooperation, a great number of rails containing transverse fissures. It is also the hope of the Bureau to eventually produce, by known mechanical means, transverse fissures in supposedly sound rails, so that an insight may be gained as to the probable service or structural conditions causing their production.

As further study into the rail problem, work has been inaugurated to determine if gagging is a vital factor in the production of transverse fissures. This work will determine the effects of gagging on rails, with relation to their life, carbon content, and type of fracture produced under alternating stresses similar to those undergone in actual service. The presence of internal stresses in railway material is also being investigated.

The investigation upon railway material has extended beyond work in the laboratory. During the year an extensive trip was made to inspect track in which four or five transverse fissures had occurred in a single mile.

With a view of obtaining machines capable of reproducing surface conditions upon rails in the laboratory, a comprehensive study has been made of such machines at present existing in laboratories of railroad companies in various parts of the country.

Investigation on the Heat Treatment of Carbon Steel.

Work toward the close of this past fiscal year was temporarily concluded on the heat treatment of 1 per cent carbon steel with special reference to the development of endurance to repeated stresses such as are met in service. This investigation has been carried on jointly at the Bureau and the Altoona shops of the Pennsylvania Railroad on, mainly, certain locomotive springs which have been a source of considerable trouble up to the present time. The investigation has been in progress for a considerable length of time. The results of this investigation will soon be published by the Bureau.

Calibration of Testing Machines.

In the last annual report, mention was made of the acquirement of an apparatus for calibrating testing machines up to 50,000 pounds capacity. These test levers have been used upon several occasions during the past year. Two of the Bureau's testing machines, one of 100,000 pounds and the other of 200,000 pounds capacity, have been compared upon several occasions with these sensitive test levers. The apparatus has also been used during the past year to calibrate three testing machines located in the laboratories of commercial organizations. The machines so calibrated were of 400,000, 200,000, and 100,000 pounds capacity. To enable the calibration of testing machines on which the test levers were too large to be used, additional smaller test levers of 20,000 pounds capacity have recently been secured. These have been used to calibrate a 4,000-pound spring-testing machine at the Washington Navy Yard.

A further study has been made of the method of comparing testing machines with those of the Bureau by means of the so-called

standard bar. By means of these comparison bars, testing machines can be approximately standardized up to their full capacity. This method was used for comparing with the Bureau machines a 100,000-pound testing machine located in the laboratory of a commercial concern. It is hoped that further development in this method will be made in lieu at this time of any more satisfactory means of standardizing testing machines to a high loading.

Large Steel Columns for Long-Span Bridges.

The investigation of the strength of large bridge columns, conducted at the Pittsburgh branch laboratory, has been completed and the results are ready for publication. In this investigation 22 columns were tested, the test specimens being constructed of various types of alloy and carbon steels. The results of these tests are of direct value to engineers and manufacturers in view of the relative scarcity of data upon the deportment of large compression members of bridges. The data submitted furnished additional evidence of the direct relation which exists between the strength of the columns and the yield points of the steels used in its manufacture, and further emphasizes the need of careful design of lattice, diaphragms, pin plates, and the other column details. These test specimens correspond throughout in design and fabrication with actual chord members of the large bridges now being erected at St. Louis, Metropolis, Ill., and Memphis, Tenn. Some of the columns were the largest which have ever been tested to destruction.

Investigation of Wire Cables.

In the investigation to determine the physical properties of wire rope, which has been conducted mainly at the Pittsburgh branch for several years, over 500 samples have thus far been tested. The diameters of these ropes vary from $\frac{1}{4}$ to $3\frac{1}{4}$ inches, inclusive. The samples are classified according to the particular uses to which they are applied in engineering practice, and comprise the more flexible grades known as tiller rope and elevator hand lines, rigging rope, hoisting and transmission rope, different grades of steel being used in the construction of the several types. The general laws of construction of the ropes and their complete behavior under static loadings are determined. The results of these static tests are being arranged for publication, the experimental work having been practically completed. Further research is being given to determine the behavior of rope under dynamic conditions of loading and service conditions. Numerous tests have been made on cables which have already been used in engineering practice, to ascertain the causes which affect their deterioration and life.

Utilization of Strain Measurements on Structures.

Several years ago a report was made on the strain gauge measurements obtained on several structures, bridges, lock gates of the Panama Canal, pavements, etc. These measurements have, as a whole, never been made available. Recently the observations made on the cross girders of the emergency dam of the Panama Canal were selected for study. The assembling of this data has been practically completed and it is expected that a technologic paper will be issued

in the near future giving a report upon this work. It is hoped that the data obtained on other structures will be likewise utilized for publication during the ensuing year.

Investigation of the Properties of Zinc.

In cooperation with the chemical and metallurgical divisions, an investigation of the properties of zinc has been inaugurated. Knowledge of the properties of this material is very deficient, and at the request of several manufacturers and users of spelter the Bureau has undertaken work which promises to be a thorough and complete investigation, the results of which will be published, it is hoped, during the coming year in the form of a technologic paper. It is planned to make an extensive series of tests in tension, torsion, transverse, cold bend, compression, shearing, and hardness upon material which has been submitted by several manufacturers of zinc.

Investigation of the Physical Character of Copper Deposits in Electrotyping Baths.

In cooperation with the chemical division, the effects of the composition and temperature of the electrolyte and of the current density upon the character of the deposits have been determined from a study of the physical properties involved, namely, tensile strength, permanent elongation after fracture, etc., of the copper shells. This work has not yet been entirely completed, especially certain tests upon the hardness as measured by the resistance to penetration and abrasion, the relations between the microstructure and the other physical properties, the effects of annealing, and, finally, service tests of copper of known structure and physical properties. Preliminary reports have already been made to several societies interested in the work.

Cooperation with Engineering Societies.

The Bureau cooperates with committees of the various engineering and scientific societies of the country, and representatives from the Bureau have assisted in this work by service on committees organized for the solution of particular problems. The classes of problems with which the Bureau is engaged in this connection include a study of cutting tools, in cooperation with a subcommittee on the cutting of metals of the American Society of Mechanical Engineering; the standardization of pipes and pipe fittings, a work that is being carried on by the National Fire Protection Association; the elimination of hazards to which industrial workers are subjected, in cooperation with the committee on protection of industrial workers of the American Society of Mechanical Engineers; the establishment of standard methods of testing, in cooperation with the committee on standard methods of testing of the American Society for Testing Materials; and the formulation of a national boiler code, which is being conducted by the American Uniform Boiler Law Society.

Information Furnished on the Strength of Metals and Alloys.

Service of a consulting nature has been rendered by the Bureau in answering the many inquiries received from correspondents seeking information as to the strength and other properties of metals and on allied engineering subjects. The assistance afforded in this connection is entirely distinct from that given in making technologic

and other tests upon materials and devices. These inquiries were received from a great many sources, including the Federal Government departments, municipal and State governments, Federal and State commissions, universities and schools, engineering societies and research laboratories, publishers of technical magazines, corporations and firms, manufacturers, and private individuals. Inquiries were received from Members of the Senate and House of Representatives, and several were received from persons located in foreign countries.

It is difficult to review the nature of these inquiries, as they relate to a wide range of subjects. A great many were requests for technologic papers and bulletins issued by the Bureau. Many were seeking information as to technical literature upon particular subjects published elsewhere than by the Bureau. Many requests were made that articles upon vital subjects be prepared and published. Advice regarding proper specifications for various materials and methods of construction has frequently been given. The questions related to manila ropes, silicon bronze wires, foundations and other branches of engineering and building construction, methods of waterproofing, malleable iron, heavy iron castings, and other structural materials. Interpretation of existing standard specifications has upon request often been made. Assistance has frequently been given regarding proper testing machines or proper testing procedure for specified purposes. These inquiries have embraced methods of making tests, formulas used for working up test data, merits of various testing devices such as the comparative value of two, three, and four screw testing machines, names of manufacturers of testing machines, etc.

The Bureau's assistance has been frequently sought in the solution of problems involving unusual or complicated applications of mechanics together with a specialized knowledge of the properties of the materials involved, such as the thickness of silver pipes to withstand required pressures; the lateral strength of iron and steel silo rods; the relative merits of cast iron, wrought iron, and steel for casing purposes for deep wells; shrinkage fits for built-up crank shafts; the strength and bending constants of poles; and many others of a similar nature. Information as to the causes of failure of manufactured materials and of structures has also been the basis of many inquiries.

Further assistance rendered by the Bureau in giving information along these general lines, but of a miscellaneous nature, and hence difficult to describe, is illustrated by the statements of the subject matter of the few following selected inquiries received: Holding power of nails in various woods, railroad engines and their upkeep, resistance to shock of alloy and heat-treated steels, tensile strength and elasticity of bed springs, modulus of elasticity and Poisson's ratio of celluloid, effect of repeated reheating on the tensile strength of metals, economical setting of return tubular boilers, proper heat treatment of steels, brittleness in steel plates, effects of loads applied for long lengths of time on wooden beams, etc.

Tests on the Strength of Materials.

There have been performed during the past year a total of approximately 870 tests of a more or less routine nature. This number plus the large number of tests of a semi-investigative nature can

be contrasted, to show the growth of the testing work during the past year, with the approximately 350 tests of the strength of materials reported in the last annual report. In a great many of these tests extensometer or compressometer measurements were taken—that is, careful determinations of proportional limit and modulus of elasticity were made.

These tests have been of every description, namely, for tensile strength, transverse bending strength, hardness, cold bend, repeated stresses, compressive strength, shearing strength, and of a miscellaneous character according to the tests desired.

Material has been submitted by practically all branches of the United States Government, as well as by a number of private corporations and individuals. The tests made on materials for the Panama Canal have usually been numerous, and a great deal of time has been occupied in not only making the particular test required but in perfecting appliances and equipment necessary for the tests requested.

Over 580 tests were made on ferrous metals. These tests included material such as structural steels, malleable iron, bolts, reinforcing and rivet steels, cast iron, shells and gun forgings, manganese steels, turnbuckles, propeller blades, axle and tire steels, blacksmith's cold chisels, nuts, swivels, wrought iron, wires, nickel chrome steel castings, etc. Mention might also be made of a tensile test on a 4½-inch diameter steel bar.

Tests amounting to 255 were made of nonferrous metals. These test specimens included bronze springs, copper blades, brass tubing and other brass samples, phosphor bronze, manganese bronze, aluminum bronze, and other bronzes, heat-treated titanium, Monel metal, duralumin, wires, zinc, dental amalgams, and other materials.

In addition, there were 35 tests made on materials of a miscellaneous nature, such as manila rope fiber, and speciments consisting of rubber adhering to steel, etc.

At the Pittsburgh branch of the Bureau numerous tests for different departments of the Government, manufacturers, and individuals were made, usually for acceptance test or proof tests of products. One of the most important of these tests was conducted upon a large cast-iron keel block, such as is placed at regular intervals under the keels of ships in dry docks. This keel block withstood a proof load of 10,000,000 pounds, the full capacity of the machine, but later burst at a repetition of loading at 9,600,000 pounds. Two other tests were carried out on full-sized floor slabs, one of hollow tile and another of laminated wooden construction, with interesting results. In addition, tests to destruction were made on four tile walls, first under transverse force and later under direct compression loading. Proof tests were made of 24 porcelain insulators, 12 inches in diameter, of the type used on high-voltage wireless towers, the specifications calling for a proof load of 500,000 pounds held for one minute. Numerous tests of a routine nature were conducted, including 83 cables, varying from ¼ to 1½ inches in diameter; 12 full-size automatic car couplers; 260 manila ropes ranging from 1 to 3½ inches in diameter; 1 street car rail; 27 6-inch granite cubes; 21 concrete cylinders, 12 inches in diameter by 16 inches; approximately 800 samples of concrete, as well as numerous tests of smaller

specimens covering brick, cement cubes, steel, semisteel pieces for roll construction, etc.

Tests of a Semi-Investigative Nature.

In addition to the large number of routine tests made during the past year, there have been frequent occasions when problems submitted to the Bureau involved tests or work of a degree approaching an investigation. These are separately reported below, since they are of a far more important character than the tests given in the summary of those made upon the strength of materials.

(1) In response to a demand from the Panama Canal the Bureau has been equipped with facilities for testing large-diameter wire ropes. As a consequence, six wire ropes of this kind have been submitted for test during the past year. These cables were of diameters varying from 2 inches to 3¼ inches. Closely allied to tests upon these wire ropes may be mentioned the tests upon seven large-size manila ropes with diameters up to 3½ inches. The results of tests upon wire cables and the methods involved in their testing have been reported, in compliance with a number of requests, in an article specially written by the Bureau and published in one of the engineering magazines.

(2) The Signal Corps of the Army has found it necessary in the development of its field service to call upon the Bureau on several occasions during the year to make tests upon materials for use in aeroplanes. Practically all classes of aeronautical materials have been tested. These have included wing coverings; special metals, such as magnalium and duralumin; turnbuckles; wires; woods, such as spruce, mahogany, basswood, and ash; cold-rolled steels, such as flats, welded and brazed; and other materials. The tests were very exhaustive upon several of these classes of materials; for example, a great many extensometer measurements were made upon duralumin, and tests upon cellone material for use as a wing covering have been made so as to include the effects of various environments upon the cellone, such as immersion in water, mineral oil, caustic soda and sulphuric acid, effects of heat, light, and ozone.

(3) It is a matter of very great importance to have a correct interpretation and understanding of the terms which are fundamental in testing engineering, such as elastic limit, proportional limit, and yield point. At the present time there is a very great uncertainty and divergency of opinion as to the correct meaning of these terms. A great many tests made by the Bureau in which all of the three have been determined upon the same material have permitted a study of the relation existing between them, if any does exist. Work has already been done in presenting the preliminary results of that study before interested bodies, such as the American Society for Testing Materials, and others.

(4) At the request of the Navy Department a comprehensive series of tests has been inaugurated and is nearing completion upon practically all of the principal steels used in the construction of warships. The steels being tested include soft or flange steels, mild steels, high-tensile steels, nickel steels, and special-treatment steels. Careful tests are being made to determine accurately, among other constants,

the proportional limit and modulus of elasticity from the stress-strain curve which can be obtained from the data.

(5) Among the problems submitted to the Bureau during the year was one to investigate the causes of failure of a seamless steel cylinder which failed while being charged with hydrogen gas. Several kinds of mechanical tests were made upon the material composing the failed cylinder, and in cooperation with the other divisions of the Bureau a detailed report was made on the material as found in the failed cylinder and in a sound cylinder similar to the one failed.

(6) Material from a boiler which failed in service on the United States revenue cutter *Unalga* was submitted to the Bureau for examination. The investigation extended over a number of months and included a study of the embrittlement of boiler plate by the action of hydrogen and the effect of boiler compound on boiler plate. Many tests were made upon the specimens cut from the failed boiler material, the purpose of the entire investigation being to determine the cause of cracking of the seams of the drum.

(7) The Panama Canal requested the Bureau to investigate a number of steel-plate specimens submitted and discovered by their inspectors to possess structural defects. An exhaustive study was made of the plates submitted, with a view of bringing out by means of cold-bend tests the so-called "snaix" present therein. The work in this semi-investigation was carried on in cooperation with other divisions of the Bureau.

(8) During the past year a large wrought-iron I bar, which failed in service on a bridge of the New York Central Railroad, was submitted to the Bureau for examination. Tensile tests were made upon the full-size pieces of the I bar, as well as upon test specimens cut in both longitudinal and transverse directions; likewise, hardness tests were made upon specimens prepared from near the original fracture. The results were combined with results obtained from other divisions of the Bureau.

(9) A series of machetes which had failed while in use on the Panama Canal, as well as a series of new blades, were submitted to the Bureau for examination and test. They were subjected in the condition as received and also, after heat treatment, to a series of physical tests, such as Brinell hardness and cold bend, the purpose being, first, to determine the variations in properties which exist in the commercial product—that is, the variations in any one blade and also from blade to blade; and, second, to see if the commercial product can be improved to a marked degree by subjecting it to a carefully regulated heat treatment. Other divisions of the Bureau cooperated in this investigation.

(10) The Panama Canal experienced difficulty with the breakage of large manganese bronze bolts on the canal. The bolts were submitted to the Bureau for examination. Investigation thereupon included tests upon a full-size bolt and several tests upon specimens cut from the material. Hardness tests and measurements of internal stresses were made. The results of the mechanical, physical, chemical, and metallurgical tests furnished the basis of the report thereon.

(11) The Ordnance Office of the War Department was interested during the year in causes connected with the failure in service of a broken elevating gun screw. This screw was a nickel-steel forging.

Tests were made at the Watertown Arsenal. The results of the tests were sent to the Bureau for study and utilization in a report by the Bureau as to the causes of failure.

Investigation and Testing of Cement, Concrete, and Stone.

The work of the Bureau on cement, concrete, and stone is of three kinds:

(1) The determination of the physical properties of cements, concretes, sands, crushed stones, gravels, building stones, plasters, and drain tile, the investigation of the durability of these materials under various conditions, and the investigation of testing methods.

(2) Special investigations of the above and other similar materials at the request of Government offices to determine whether they are satisfactory under special-service requirements.

(3) The testing of samples of cement submitted by various Government offices to determine whether the cement meets the requirements of specifications upon which it is purchased, together with sampling of cements at the point of manufacture and supervision of shipments under Government seal.

Standard Specifications for Portland Cement.

Meetings of the joint conference of representatives of the United States Government, the American Society of Civil Engineers, and the American Society for Testing Materials were held during the year and final agreement was reached on one specification for Portland cement, which was recommended to all three organizations for adoption. The cement committee of the American Society for Testing Materials has adopted this specification, with some modifications. The civil engineers and the Government committees have not yet taken action. The recommended specification includes several modifications from previous existing specifications, which it is believed will furnish a cement of improved quality. The United States departmental conference on cement specifications which was organized by the Bureau of Standards will probably take action upon this specification during the ensuing year.

Foreign Specifications for Portland Cement.

A collation is being made of all foreign specifications for Portland cement. This information is being obtained by the assistance of the various consular agents. A paper will probably be published on this subject during the ensuing year.

Studies of the Constitution of Portland Cement.

There is now being printed a paper dealing with the physical and chemical properties of the constituents of Portland cement when prepared in a pure condition. These have not only been studied by themselves, but also when ground together in various proportions, including that in which they are present in Portland cement. The strengths developed by these pure compounds and the mixes have been determined, as well as the amount and character of the hydration at various periods. It is very interesting to know that the tricalcium silicate alone has all the properties of commercial Portland cement, but the dicalcium silicate hardens very slowly, and to prevent breaking the specimen, they must be handled with the greatest care, even at the end of four weeks. However, in six months

it has a strength approaching that of Portland cement. The tricalcium aluminate hydrates almost instantaneously with a great evolution of heat, but never attains any marked strength.

Constitution of Portland Cement as Affected by Changes in Composition.

This constitutes one of the principal investigations of the Bureau dealing with this important material. It has been carried on by making cement in the miniature cement plant at the Bureau in sufficient amounts to allow of the making of 6-inch by 12-inch concrete cylinders, in addition to the small specimens. This work has advanced to such an extent that all the cement desired has been made and one-year tests obtained on all. The number of cements made (74) and the desire to wait for longer time tests has delayed the issuing of reports covering the work. It is hoped, however, that during the coming year a preliminary report will be issued.

In this same investigation there were a number of cements made containing large amounts of magnesia. The results of these tests have been studied and a paper prepared which will be submitted for publication in a few months. When this work was started the standard specifications for cement did not allow more than 4 per cent magnesia. The results obtained show that this amount might be largely exceeded without any marked difficulty being encountered, and a preliminary paper has been read to this effect. Recently the American Society for Testing Materials agreed to submit to letter ballot of that society specifications allowing 5 per cent of this constituent.

Effect of Fine Grinding of Portland Cement.

There has been much discussion as to the value of fine grinding of cement, the tendency being to require finer grinding, although little is known as to its effect. On this account it has been deemed advisable to investigate the effect of the fineness of cement on its strength and other physical properties.

In connection with these investigations, it was necessary to develop an apparatus for the purpose of separating in quantity the "flour" of Portland cement from the coarser particles. Three grades of fineness are being obtained with the separator, the coarsest of which readily passes the 200-mesh sieve. Several brands of Portland cement are also being reground to various degrees of fineness to be tested in concrete. A great deal of work has been done on the investigation during the past year. About 4,000 test specimens for tensile and compressive strength have been made on 38 samples. These consist of different brands of Portland cement of varying degrees of fineness. These tests are to extend over a period of several years; at certain intervals the specimens made are being tested. The results so far obtained indicate that finer grinding increases the cementing value. On the average for each 1 per cent increase in fineness the compressive strength in concrete is increased 2 per cent. It will probably be a year or more before conclusive results will be available.

Granular Analysis of Cement.

An apparatus for the granulometric analysis of material has been developed at the Bureau of Standards. The granulometric analyses

may be said to supplement the sieve determinations. On account of the lack of uniformity in the size of openings of the 200-mesh sieve, the determinations by the air analyzer are more accurate as to the limiting size of particle in each degree of fineness obtained. In routine work determinations of three degrees of fineness are made with the air analyzer, the "flour" separated in the coarsest determination all readily passing through a 330-mesh sieve. In addition to the usual analyses of clay, hydrated lime, ground sand, litharge, red lead, etc., the analyzer has been very much simplified and made more compact by the design of a regulator to replace the cumbersome oil tank and air reservoir previously employed. The regulator replacing these weighs only about 3 pounds. Various investigations of the fineness of Portland cements have been made with the analyzer, among these being the mechanical analyses of cements used in the investigations of the effect of fine grinding on the strength of mortar and concrete. In cooperation with the Bureau of Mines and the Bureau of Chemistry a special form of the analyzer was developed for the study of dust explosives. With this apparatus much finer separations of material may be obtained than was possible with the original analyzer.

Air Separator for Cement.

An apparatus has been devised for the separation of "flour" from the coarse material of Portland cement by means of air. Flour of three degrees of fineness are now obtained. These three degrees of fineness correspond to the three sizes obtained on the air analyzer. A new stack for the separator has been designed and constructed. This stack increases the capacity of the machine. Quantitative separations are being made of flour of different degrees of fineness on the strength of concrete and mortar.

Standard Cement Sieves.

Fifty-nine 200-mesh sieves have been calibrated during the year to determine whether they meet the Bureau's modified sieve specification which was adopted in 1914. This service has been of much assistance to testing laboratories, since a correction factor is furnished with the certificate of test. The application of this correction factor makes possible much greater concordance of results than were previously obtainable, thereby preventing many disputes between the manufacturer and consumer. With the increase in the fineness requirement of specifications for cement, this work should be of still greater service to the public.

Standard Fineness Sample.

During the previous fiscal year a standard fineness sample was prepared and issued by the Bureau to testing laboratories so that they might calibrate their own sieves or check their sieving methods. The samples are guaranteed to be correct within 0.2 per cent as determined on the fundamental standards maintained by the Bureau and are issued in two degrees of fineness. During the year 86 samples have been issued.

Investigation of Some of the Raw Mixes Used by Various Portland-Cement Manufacturers in the United States.

Seventy-three raw mixes, used in making Portland cement by various manufacturers, have been burned at five different temperatures (1,370, 1,400, 1,435, 1,470, and 1,500° C.) in a stack kiln. After burning each raw mix was examined petrographically to determine the degree of burning. It was noted that the average temperature at which satisfactory cement was produced was 1,435° C. Six raw mixes were well burned at 1,370° and about the same number required a temperature of over 1,500°. To study the effect of length of time of burning at any definite temperature, one set of burns was made at which the temperature was held at 1,335° for 1 hour and 20 minutes and another at which the temperature was held at 1,400° for the same period. These long heatings were about equivalent to the shorter heatings at 100° higher temperature.

Attempts to determine the softening points of the mixes have not been satisfactory. None of the materials in the form of a cone developed a softening point at 1,750° C. Furthermore, it was noted that the more fusible constituents had a marked tendency to flow out of the cone, leaving a skeleton of very infusible material behind.

Hydraulic Properties of All the Known Compounds of Silica, Lime, and Alumina.

Silica, lime, and alumina constitute not only by far the major portion of Portland cement, but also the major portion of natural cement, tufa, puzzolana, and metallurgical slag. When all the possible compounds of these three are known, it is of much interest to know which of these, in addition to those existing in Portland cement, possess hydraulic properties. In making this investigation, the compounds were prepared in a pure condition, ground, and made into neat and 1:3 mortar tension specimens and 1:3 mortar compression specimens. The amount and character of the hydration is also being followed, both chemically and microscopically. At the end of 13 weeks none of these, excepting those existing in Portland cement and the aluminates, have shown any marked degree of hydration.

Hydraulic Cements Other than Portland Cements.

The investigation dealing with this subject, which was mentioned in the last annual report, has been continued. The results have been even more surprising than anticipated. The cements made by burning limestone and alumina in the proportion of 65–75 parts of alumina to 25–30 parts of lime in a rotary kiln, and grinding the clinker, have produced concretes which gave at early periods strengths far in excess of those obtained from Portland cement. Thus, one burning of such a material gave as a 1:1½:4½ gravel concrete strengths of 2,800 pounds per square inch at the end of 24 hours, 3,200 at the end of 7 days, 3,300 at the end of 28 days, and 4,150 at the end of 13 weeks. Concrete of another burning gave strengths of 3,000, 4,150, and 4,750 pounds per square inch at the end of 24 hours, 7 days, and 28 days, respectively. Concrete of a third burning gave strengths of 2,950, 6,000, and 7,100 pounds per square inch, at the end of 24 hours, 7 days, and 28 days, respectively. Long time tests of concrete are not yet available, but longer tests of the neat and 1:3

mortar specimens, stored in water, tend to show that this material would not be very well adapted to the continuous action of water. The specimens stored in air, however, seem to have satisfactory strengths at the late periods.

Burnings of these aluminates, in which silica and iron oxide were introduced in rather large amounts, show that these can not be present in amounts very much above 12 per cent. If this amount is exceeded, the strength of the concrete is decidedly reduced.

Physical Properties of Sand Cements (Silica Cements).

During the past two years a study of the physical properties of several sand cements has been made. This work was continued and the results to date have been collated and will be published this ensuing year. Cements of this character have been extensively used on Government work. The tests to date indicate that concrete containing sand cement as the binding material is inferior in strength to concrete containing the same amount of Portland cement. The difference in strength of the two concretes becomes more marked as the ratio of the cement to aggregate decreases.

Value of Tufa Rock and Volcanic Ash as a Material for Admixture with Portland Cement.

At the request of the United States engineer office at Honolulu, Hawaii, an investigation was made to determine the suitability of different tufa rocks and volcanic ash found in that Territory for use as material for admixture with Portland cement and hydrated lime to produce a cheaper but satisfactory cement for building purposes. Various mixtures of the different tufa rocks with Portland cement and hydrated lime were made and ground to a fineness equal to that of Portland cement and used in place of Portland cement to determine its strength in mortar and concrete. Practically all the tests have been completed. The results to date show that one of the tufa rocks when mixed with 20 per cent hydrated lime yielded a cement of sufficient strength for use in brick masonry and mass concrete, while mixtures of 50 per cent Portland cement with 50 per cent of two of the tufa rock materials gave a concrete of 60 to 90 per cent of the strength of similar concrete in which Portland cement alone was used as the cementing material. It is expected that as soon as the six-month tests are completed a report on the subject will be issued.

Value of the High-Pressure Steam Test of Portland Cement.

The investigation of the value of atmospheric and high-pressure steam tests as a means of determining the soundness of Portland cement has been continued. This test has been exploited during the past few years by some engineers and widely discussed in the technical press. The results obtained to date indicate that cements meeting the requirements of this test are no stronger or more durable when employed in concrete under normal conditions than cements passing the present standard cement specifications but failing to pass this test. The three-year tests which have been completed confirm the conclusions drawn from previous results.

Use of the Cement Plant of the Bureau by the Public.

A very necessary part of the experimental cement plant and of the Bureau is its rotary kiln (2 feet in diameter and 20 feet long).

The use of rotary kilns is constantly increasing, but there is a desire felt by a great many to make experiments to determine if such a kiln would be satisfactory for some certain material not usually burned in such a kiln. Since there are only a few kilns in the country, the Bureau has been asked to make experimental burnings in its kiln. It has done so on a number of occasions for a nominal fee. Such burnings as the calcining of clay and limestone, the dead burning of magnesite and dolomite and gypsum, the nodulizing of iron ore, and burning of pigments have been made, in addition to the burning of cement clinker.

Durability of Concrete in Sea Water.

The investigation of the effect of sea water on concrete has been continued during the year by the inspection of several additional structures, microscopical examination and chemical analysis of numerous samples, and the collation of additional information on the condition of concrete and methods employed in construction in various harbors of the world. These data are being obtained through the various consular agents and reports have been received on a large number of structures. The investigation has shown that all concrete exposed to sea water irrespective of location is subject to chemical disintegration unless properly fabricated and protected. If sufficient care is taken the concrete will be durable. It is anticipated that the results of this investigation will be published during the ensuing year.

Durability of Concrete in Alkali Waters.

This investigation was started in 1913 and was instituted because of its importance to various branches of the Government using concrete in irrigated districts, where the alkali occasionally becomes concentrated in the soil, and as a result of the many requests received for information on the subject. The investigation is conducted in cooperation with the Reclamation Service, the drainage division of the Department of Agriculture, and the Portland Cement Association, to determine the durability of concrete of various kinds in concentrated alkali soils and methods of mitigating failure. As part of the investigation some 8,000 specially prepared draintile made under the Bureau's supervision were installed in concentrated alkali soils in Colorado, Montana, Wyoming, Arizona, Washington, New Mexico, and Utah. A number of these tile are taken up and tested each year. The results of the first year's tests were published in Technologic Paper No. 44. As an extension of this work a large number of concrete blocks were made, using aggregates to be found on the various projects as well as an aggregate of known excellent quality at Denver. These blocks were installed in localities similar to those in which the draintile were installed and are to be examined from time to time for indications of disintegration. A second progress report has been prepared, to be published as a technologic paper. This paper contains the results of the first two years' tests of draintile and a statement of the condition of the concrete blocks after six months' exposure. The results show that concrete and cement draintile will disintegrate in some of these soils unless the best of materials are used and special care is exercised in fabrication. Additional tests are to be made from year to year and the report amended as results are available.

Investigation of Integral Waterproofing Compounds.

Many inquiries are received by the Bureau for information on the value of integral waterproofing compounds for use in cement mixtures. In 1912 a number of cement stucco panels, approximately 3 by 12 feet in size, were erected, in which various integral waterproofing compounds were incorporated. These panels have been exposed to the weather and observations made from time to time. Their present condition indicates that none of the so-called integral waterproofing compounds tested have material value when used in stucco to reduce dampness; some of them are deleterious and cause cracking and disintegration. About 10 per cent by volume of hydrated lime appears to appreciably decrease the water absorption property of the stucco and has no deleterious effect. This work is being continued by the erection of several large panels containing waterproofing compounds in connection with the general stucco investigation.

During the year a cooperating committee was organized, composed of representatives from Government offices, engineering societies, and the various industries, including all known manufacturers of waterproofing compounds. This committee cooperated in planning a series of field experiments, which contemplates the construction of concrete tanks by contract, both with and without waterproofing compounds. These tanks are to be located below grade near the Potomac River and subject to tidal water. A questionaire was also prepared and submitted to architects, contractors, and engineers to gather information on the present usage of these materials. Results of this investigation should be available during the ensuing year.

Accelerator for Hardening Concrete.

At the request of the United States Engineer Office at Memphis, Tenn., an investigation was made to develop a method of producing a concrete which would have considerable strength in a comparatively short time. A concrete of this character was desired as a substitute for willow mats for use in revetment work on the Mississippi River. The decline in the supply of willows available for this purpose necessitated the finding of a suitable substitute. The results so far obtained show that a 4 per cent solution by weight of calcium chloride in place of the mixing water would materially accelerate the hardening of concrete, but does not appreciably affect the time of setting. This acceleration varies somewhat with different cements. With some cements in 1:2:4 concrete, it was found that the strength increased about 100 per cent in 24 and 48 hours. This, it is believed, is due to the more complete hydration of the silicates and aluminates, since it was found that they were more completely hydrated when the calcium chloride was used. Its use increases the cost of concrete 12 to 15 cents per cubic yard. For best results, it is important that the concrete be mixed to a quaking or mushy, but not fluid, consistency. Calcium chloride should be used with caution in reinforced concrete, as the presence of the calcium chloride will accelerate any corrosion of the reinforcement which may occur. The work is being continued.

Compressive Strength of Portland-Cement Mortars and Concretes.

A study was completed of 20,000 tests of Portland-cement mortars and concretes collated from the many investigations made by the Bureau of Standards and the structural materials laboratories of the Geological Survey, which were transferred to the Bureau of Standards in 1910. These data have been published in Technologic Paper No. 58, Strength and Other Properties of Concretes as Affected by Materials and Methods of Preparation. The results show that several of the generally accepted methods for proportioning concrete mixtures are incorrect and that certain precautions are necessary in the fabrication of concrete to insure a product of known quality. The effect of variation in the quantity of cement used, the effect of different exposures while hardening, the effect of aging, etc., are discussed. The relative value is shown of various aggregates, such as gravels, limestones, granites, trap rocks, cinders, sands, and stone screenings, also the relative value of rounded and sharp-grained sands. Proper methods for testing and selecting aggregates are also suggested. This paper should be of particular interest to contractors and engineers.

Tests of Composite Concrete Floors.

During the year loading tests were made on several concrete floors. The tests consisted of determining the deflection produced in the floors when subjected to a superimposed load equal to three times the working load for which the floors had been designed. Tests were made on several floors for acceptance in the new chemical building of the Bureau of Standards on solid two-way reinforced floors and on combination hollow tile and reinforced concrete floors.

A type of floor which is being introduced into Washington, known as the Schuster two-way reinforced hollow tile and concrete floor, was also investigated to the extent of making loading tests.

Value of Various Materials as Concrete Aggregate.

In cooperation with State geologists and others, representative samples of mine tailings, crushed slag, sands, gravels, and stones are being obtained for test to determine their suitability as aggregate for concrete mixtures. Many inquiries are received concerning the value of these materials. The results of the investigations will probably be published in State reports and subsequently in Bureau papers.

Investigation of the Value of a New Type of Concrete Mixer.

This investigation was undertaken in cooperation with a contractor for the purpose of determining the value of mixing concrete by a new process. Over 300 concrete cylinders were made of concrete mixed by the new method and by a present commercial method in order to obtain comparative results. The tests completed to date show that the new method is not satisfactory and does not produce concrete equal in quality to that produced by present commercial methods.

Effect of Moisture and Temperature Changes on Concrete.

Work was continued on the investigation of the action of concrete when subjected to a variation of temperature and moisture condi-

tions. The present work has been confined to making strain gauge measurements on concrete roads and pavements with the ultimate aim of determining the most effective distance for the spacing of transverse joints in concrete. During the past year numerous measurements have been made on experimental slabs installed on the Bureau grounds and on a Delaware road. The results confirm those previously obtained.

For the past two years measurements have been made with a Berry strain gauge on concrete roads to determine the expansion and contraction taking place in the concrete. This instrument can not be applied in the measurement of movements in green or uncured concrete which has not set fairly well, as, for example, concrete less than 24 hours old. To meet the demand for an instrument suitable for making measurements on concrete at early ages, and also to effect a greater accuracy in all the measurements, it was decided to make use of the principle of a comparator. Consequently a comparator of a portable type has been designed and constructed at the Bureau's instrument shop. This instrument consists of two micrometer microscopes mounted in a vertical position on a horizontal shaft and a reference bar of invar metal fastened in a horizontal position a few inches in front of the base plate and attached thereto. By measuring with this comparator the volumetric changes which take place in concretes, plasters, stuccos, etc., under various weather conditions, it is anticipated that considerable can be learned as to the causes of the cracking which so often occurs in these materials.

Apparatus is being constructed for determining the thermal coefficient of expansion of concrete. The apparatus will consist of three concentric steel cylinders, so arranged that a concrete cylinder, 6 or 8 inches in diameter and 40 inches long, can be placed in the central steel cylinder and a fine wire hung over each end of the concrete specimen in such a position that readings can be taken on the wires with a portable comparator, measuring the length changes of the concrete to an accuracy of 0.0001 inch. The concrete will be brought to the desired thermal conditions by circulating a liquid around the inner metal cylinder. The whole apparatus will be insulated by a casing of cork 4 inches thick.

Freezing Tests of Concrete.

The hardening of Portland cement being almost entirely the result of the chemical action of water on certain constituents present in it, it follows that this hardening would be materially affected by changes in temperature. Owing to various reasons, it is necessary to continue building operations through the cold season. Under such conditions concrete does not harden rapidly, with the result that on a number of occasions concrete buildings have collapsed, owing to the removal of the forms before the hardening had sufficiently advanced. It is of much interest, therefore, to know to what degree concrete is affected by freezing temperatures, and an investigation has been undertaken during the last year with this in view. A large number of concrete cylinders were made which were subjected to alternate freezing and thawing during periods of various length; some after a preliminary period of hardening for a definite length of time, and others after a preliminary period of freezing for a definite length

of time. Some of the results will not be as satisfactory as desired, and may require duplication under somewhat different conditions. Thus it was found that concrete specimens which were frozen without preliminary hardening were damaged in handling after first thawing out before they hardened. It appears that all specimens which were first frozen should have been left in the molds until after one or more periods of hardening, no matter how long the first period of freezing.

Automatic Freezing and Thawing Apparatus for Testing Building Stones.

The automatic freezing and thawing apparatus for testing building stones is a unique apparatus designed by the Bureau for the purpose of determining the ultimate effect of alternate freezing and thawing of building stones and other porous structural materials. Actual observations have quite thoroughly established the fact that all kinds of stone, slate, brick, concrete, etc., will disintegrate in time when exposed to the action of frost, especially in humid climates like the eastern portion of the United States. This action is believed to be caused by the freezing and consequent expansion of the water held in the pores of the material. Many instances are noticeable in Washington where sandstone balustrades on buildings less than 50 years old show unsightly effects of disintegration. It is quite possible that the pronounced cracks in the marble of the Washington Monument are due partly to frost action. It is important to determine the effect of frost action on the different structural materials that are susceptible to disintegration. Tests have been made at this Bureau and elsewhere for a number of years to determine the effect of freezing on different materials, but the burdensome process formerly followed made it impractical to continue the tests far enough to obtain in most cases any definite results. This apparatus is designed to automatically move a charge of stone, concrete, or other material back and forth from a freezing chamber to a thawing chamber at the intervals required to completely congeal and thaw the contained moisture. With this apparatus it is expected that 80 or 100 freezings can be made in one day, which by the usual method would require several weeks' time to complete. Hence it will be practical to make a great number of freezings on a sample of stone or other material and the number of freezings required to bring about a certain degree of disintegration in the material can be determined. The number of freezings required to bring about this degree of disintegration being determined, the relative length of service that can be expected from different materials can be established. By comparison of these results with actual observations on structures showing disintegration at the end of a known period of exposure, it will be possible to predict with some degree of accuracy the number of years' service that can be expected from any material under these conditions.

Investigation of the Building Stones of the United States.

In connection with the cooperative investigation of building stones which is being carried on in cooperation with the Geological Survey and Bureau of Mines, 200 samples of marble, limestone, sandstone, and granite have been collected from various quarries in all

sections of the country. The testing work has been confined chiefly to the marbles, and includes the determination of compressive strength, on wet and dry specimens, on bed and on edge, transverse strength of perpendicular and parallel to bed, tensile strength perpendicular and parallel to bed, percentage of water absorption, specific gravity, weight per cubic foot, porosity, hardness, coefficient of expansion, heat conductivity, electrical conductivity, and resistance to the action of frost. Various building stones submitted by other Government departments and State governments have been investigated to determine their suitability for particular purposes. A collection is being made of samples of all the important building stones for the establishment of a permanent file. At present 75 slabs of polished marble, 8 inches by 12 inches, have been collected from typical quarries in the Eastern and Southern States. These will be filed in a manner to enable persons interested to study and compare the general features of the different types. This collection when complete will consist of samples from all the principal quarries of the country. A paper containing the results of the tests available on building stones will probably be published during the ensuing year.

Investigation of Granite for Breakwater Construction.

Samples of granite were tested for the United States Engineer Office, Wilmington, N. C., to determine their suitability for use in breakwater construction. This investigation included tests to determine the action of sea water and the action of frost on the different types.

Investigation of Granite for Curbing.

A number of samples of granite were tested for the Commissioners of the District of Columbia, to determine the most suitable for curbing purposes. The tests established the fact that the granite most suitable for curbing was the one that could be procured at the lowest cost.

Stucco and Plaster Investigation.

A series of tests, primarily to determine the comparative durability of various types of plastered metal lath on exterior walls, was undertaken in 1911. The results of these tests, obtained from the exposure of small panels, indicated the necessity of carrying out an investigation on a much larger scale. Accordingly a new and more comprehensive series of tests was planned, the program of which was put into the hands of a cooperating committee consisting of representatives from the Government, engineering societies, the Associated Metal Lath Manufacturers, the Portland Cement Association, the Gypsum Industries Association, the National Lime Manufacturers Association, the Hollow Tile Manufacturers Association, and a number of contracting plasterers. The recommendations of this committee were followed in the construction of a test structure, approximately 200 feet long, 26 feet wide, and 24 feet high, the exterior walls of which are divided into 56 panels approximately 15 feet wide and 10 feet high. These panels are constructed of terra cotta hollow tile, monolithic concrete, brick, gypsum block, plaster board, and wood and metal lath and are plastered with a number of

typical stuccos, the work being carried out under the supervision of the cooperating committee. The structure was completed in November, 1915. A progress report has been prepared, giving a full description of the test structure and the results of a careful inspection of the condition of the panels in April, 1916. The report indicates that only about 40 per cent of the panels were in satisfactory condition, and only two panels were found to be entirely free from cracks. No general recommendations are given in the first progress report nor will such recommendations be attempted until additional test panels have been erected and an extensive field examination made of stucco houses which have been standing five years or longer. The report, however, contains many illustrations and much suggestive information of value to architects, builders, and prospective home owners. A program has been approved which contemplates the immediate construction of additional panels. This report will be amended from year to year as results become available.

Routine Cement Inspection and Testing of Cement and Concrete.

Cement was inspected during the year at 22 different cement mills located in Virginia, Maryland, Pennsylvania, New Jersey, and New York. The inspection work included the taking of samples, their testing, and subsequent supervision of packing and shipment to the various departments and offices of the Government. A total of 8,839 samples were tested for the Navy and War Departments, Bureau of Lighthouses, Panama Canal, Supervising Architect's Office, District of Columbia, Lincoln Memorial Commission, etc. Inspection was made of 528,200 barrels of cement for shipment to Panama, and 234,096 barrels for shipment to Government departments in the United States, for use in the construction of Federal buildings, river and harbor improvements, etc. Cement was inspected for export for one company and certificates of the quality were furnished previous to shipment to Argentina. The inspection of all cement used by the District of Columbia necessitated that an inspector be stationed permanently at the cement mill in Maryland. Shipments to the District have ranged during construction periods from one to four carloads daily.

At the Pittsburgh branch of the Bureau the routine testing of cement and concrete for the public and the various departments of the Government has been less than in previous years. Local inspectors have been maintained at three different plants, but sampling and shipping has fallen off about one-third from that during the previous year. During the year 189,000 barrels of cement were sampled and 207,000 barrels shipped, the excess in shipments being due to material sampled during the previous year. It is interesting to note that the Bureau has not been called upon to reject any cement. All cement submitted proved satisfactory, although 14,000 barrels were withdrawn by the manufacturers after the material was sampled but before it was tested. The decrease in the amount of testing required permitted the Bureau to render assistance to a number of scientific organizations engaged in preparing specifications for cement and concrete and in carrying out investigations according to their directions.

Miscellaneous Tests.

During the year a total of 473 miscellaneous samples, consisting of sands, screenings, gravels, stones, asbestos roofing boards, gypsum, magnesite cements, concrete, waterproofing compounds, alkaline soils, and waters, were received for test.

Information Furnished as to Cement and Concrete.

Many inquiries were received during the year from architects, engineers, contractors, and builders, who sought information concerning methods of waterproofing concrete, the value of waterproofing compounds, methods of construction to be employed in sea water, effect of using sea water for mixing concrete to be placed in sea water, physical properties of concretes of various mixtures, the cause of staining of plaster walls and ceilings, the relative value of various concrete aggregates, methods of making magnesite composition floors, methods of preventing dusting of cement floors, methods of designing concrete road slabs, suggestions for building-code requirements, the cause of failure of concrete structures, durability of cement draintile, the effect of sewage on concrete, the physical properties of marbles, methods of treating stone to reduce absorption, specification for stucco, fire-resisting properties of structural materials, the corrosion of metal lath, reinforcement of gypsum plasters, the interpretation of cement specifications, methods of coloring concrete, etc.

From the general public requests were received for information on methods of mixing concrete, laying of concrete sidewalks, waterproofing basements, suitability of various materials for use in concrete, durability of concrete in sea water, durability of composition magnesite floors, the physical properties of stone, the cause of failure of draintile, the effect of frost action on concrete, suitability of concrete for oil and acid storage tanks, quality of American Portland cements, damp proofing brick and tile walls, dusting of concrete floors, corrosion of metal lath, etc.

From cement manufacturers, architectural stone manufacturers, and commercial testing laboratories requests were received for information on the accuracy of sieves, the physical properties of concrete, the value of fine grinding, the value of silica cements, cause of failure of draintile, the interpretation of cement specifications, value of sieve-agitating machines, quick-hardening concrete, standard fineness samples, standard methods of testing, etc.

Publications on Cement and Concrete.

The following papers were published during the year: Technologic Paper No. 44, Investigation of the Durability of Cement Drain Tile in Alkali Soils; Technologic Paper No. 48, An Air Analyzer for Determining the Fineness of Portland Cement; Technologic Paper No. 47, Value of the High Pressure Steam Test of Portland Cements; and Technologic Paper No. 58, Strength and other Properties of Concretes as Affected by Materials and Methods of Preparation. One paper is in course of preparation and will be published as Technologic Paper No. 70, Durability of Stucco and Plaster Construction.

Properties of Hydrated Limes.

In 1915 the American Society for Testing Materials adopted the standard specifications for hydrated lime. It was desired to learn just how the material made by different manufacturers compared with the requirements of these specifications. This will serve the double purpose of giving information as to the qualities of different brands of hydrated lime, and also enable one to form an opinion as to the justice of certain limiting values placed in the specifications. At the present time samples have been examined from about one-fourth of all the factories in the United States.

Decomposition of Calcium and Magnesium Hydroxides.

Hydrated lime consists chiefly of calcium hydroxide and generally contains more or less magnesium hydroxide. In the ordinary process of manufacture there is a danger of forming a hydrated lime which has "burned during hydration," a gritty, nonplastic, yellow material, which has a tendency to expand when wet. It is supposed that this phenomenon is caused by partial decomposition of the calcium hydroxide due to the heat generated during the slaking. A study of the temperature required to decompose calcium hydroxide under different conditions was undertaken to eliminate, if possible, this difficulty.

It is frequently desirable to distinguish between the free and combined water in hydrated lime. It is therefore necessary to know to what temperature the hydrate can be heated without decomposing either the calcium or magnesium hydroxide.

Hydrated Lime in Concrete.

Hydrated lime, in small amounts, is being added to a great deal of the concrete now being used for various reasons. It is important to know how such an addition will affect the properties of the concrete. At the request of the Bureau an advisory committee, composed of engineers, contractors, and lime and cement manufacturers, has helped to plan an exhaustive research on this subject. It is hoped to determine (1) what proportion of hydrated lime is best for different kinds of concrete, (2) whether or not there is a difference in the behavior of high calcium and high magnesian hydrate, and (3) what effect hydrated lime has on the following properties of concrete: Compressive strength, segregation of aggregate, adhesion to reinforcement, resistance to abrasion, resistance to sea water, expansion, absorption of water, and permeability to water.

Working Quality of Lime Mortar.

The value of lime as a wall plaster depends not only on its plasticity, but on its ability to retain water, so that it may be spread freely on the absorbent surface of the preceding coat. A method has been devised for measuring this so-called "working quality" by spreading the mortar on a standard absorbing surface and adopting a standard means of determining when it has dried out so much that it can no longer be worked.

Properties of Lime-Cement—Sand Mortars.

It has become general practice to add small quantities of hydrated lime to cement mortars, either for plastering or masonry, in order to

make them work more freely. It is desirable to know just what effect this lime has on the properties of the mortar. A large number of mortars of varying proportions of the three ingredients have been tested for compressive and tensile strengths when stored in air or under water, expansion, adhesion to brick, and plasticity.

Measurement of Plasticity and Sand-Carrying Capacity of Lime.

These two properties of a lime are of great importance commercially, yet their measuremnt has always been an extremely difficult matter. A method for making this measurement has finally been developed, and an instrument has been built for the purpose. The method is based on the theory describing the behavior of a plastic body when compressed. A lime paste or mortar is molded into form and immediately subjected to compression. As the load is increased the body will deform and eventually rupture. The load required to produce rupture and the amount of deformation before rupture are found to depend upon the plasticity of the material.

Sand-Lime Brick.

A technologic paper has been prepared describing the process of manufacture and properties of this rather new building material.

An investigation has been undertaken to learn what effect may be produced by varying certain steps in the process of manufacture. It is hoped that the results will be of value by making possible a more enlightened supervision of the factory. It may be found that by slight variation of some of the steps in the process a better brick can be produced at the same cost. The factors which are being investigated include the qualities and proportions of sand and lime, the amount of water added before molding, the pressure used in molding, the pressure of the steam in which the bricks are cured, and the duration of the curing process.

Gypsum.

A committee of the American Society for Testing Materials is endeavoring to write specifications for gypsum and gypsum products, which are largely used as wall plasters and fire-proof partition tile. Among other things, the committee desires to develop standard methods for testing the material. This Bureau has cooperated by carrying out some of the necessary laboratory experiments to determine whether any of the methods now in use is better than any other and to devise new methods when needed. The tests at present being investigated are chemical analysis, microscopic examination, normal consistency, water-carrying capacity, time of set, tensile strength, and sand-carrying capacity.

General Properties of Clays.

An increasingly large volume of data is being collected with reference to the general properties of clays for the purpose of establishing standard tests and a system of classification of clays. This study embraces also such special classes of materials as the steatite clays of California, argillaceous sandstones, etc. A new differentiation of clays has been worked by the determination of the ratio of shrinkage to pore water volumes.

Purification of Clays.

The remarkable effect of small quantities of caustic soda and silicate of soda in bringing about a sharp separation of the fine clay particles from the granular impurities, to which attention has been called repeatedly in papers issuing from the Bureau as early as 1910, has been made the subject of a publication, Technologic Paper No. 51. The principles underlying this separation are clearly outlined. At the same time the deposition of washed clay upon surfaces, charged electrically (positively), invented by Count Schwerin, is discussed and it is shown that the purification can be effected without the use of the electric current.

In this publication the effect of varying amounts of sodium carbonate and sodium silicate upon a number of American kaolins is shown, using as a criterion the fluidity of clay and water suspensions, measured by means of a simple apparatus. In this manner useful information has been obtained for the study of the casting process, a method of forming clay products gaining rapidly in industrial application. The effect of time and the application of a vacuum are likewise discussed. Consideration has been given also to the interaction of the different clays and to the absorption of the alkali by clays.

A large number of tests have been made in connection with the purification of clay, especially from southern States. In some instances very excellent results have been obtained in the treatment of ball clays. In one instance an excellent clean-burning plastic-bond clay was washed out from a wad clay of poor appearance.

European Bond Clays.

In the manufacture of graphite crucibles, glass pots, and similar products, considerable quantities of plastic bond clay have been imported from Europe, principally Germany. The cutting off of this supply was found to be quite a hardship until readjustments could be made through the use of domestic materials. In order to make possible a comparison of American clays of this type with those of Europe, the Bureau undertook a study of the imported materials with reference to their physical and chemical qualities. This work is completed and the information will be published as Technologic Paper No. 79. It has also been pointed out that bond clays of the desired quality are available in the United States and that very satisfactory results can be obtained by the use of mixtures of two or more plastic fire clays of this type.

Paper Clays.

In cooperation with the paper laboratory of the Bureau, the clay laboratory is making a study of different American kaolins considered for utilization in the paper industry. Such physical characteristics as color, fineness, and rate of sedimentation are being determined. It has been shown that with certain kaolins the cream color can be neutralized by the use of very minute amounts of sodium ferrocyanide.

Sizing of Calcined Clay.

In the making of glass pots, sanitary ware, saggers, etc., from 50 to 60 per cent of the mixture consists of grains of calcined clay and

the remainder of plastic bond clay. The sizing of the calcined clay grains (grog) is very important with reference to the mechanical strength and density attained. In order to throw light upon this subject, an extensive series of tests was made for the purpose of determining the combination of sizes most favorable to developing maximum mechanical strength. At the same time the question of selecting the most suitable bond clays was taken up. This work has resulted in arriving at mixtures of excellent mechanical strength, well suited for saggers and other refractory articles.

Glass Pot Mixtures.

In cooperation with a large glass factory, tests are under way for the purpose of ascertaining that mixture of American clays showing the greatest resistance to corrosion by the fluid glass.

Porcelain from American Clays.

The work on porcelains has been continued and a considerable quantity of Marquardt refractory porcelain has been produced, formerly obtainable only from the Royal Manufactory at Berlin. The composition and method of manufacture of this product have been made public. Table porcelain made entirely from American clays has been produced by the European firing process as well as by a modification of the American firing method. In the latter case a special leadless glaze has been worked out. Chemical porcelain has likewise been made.

The most easily fusing mixture of feldspar and steatite has been determined.

By means of microscopic examination, the structures of the important porcelains of the world have been studied and the process of vitrification and crystallization made clear.

Considerable cooperative work has been done for the purpose of overcoming practical difficulties. Numerous tests have been made of imported French flint used in porcelain manufacture for the purpose of determining the amount of admixed quartz.

Glazes and Colors.

A considerable number of glazes have been worked out for different manufacturers of pottery and other products, representing various colors. For refractory porcelain, a special matt glaze has been developed having only a short softening range and which is useful for such products as pyrometer tubes, since it does not cause the latter to stick at the usual furnace and kiln temperatures.

Enameled Iron.

Work has been undertaken upon the study of enamels for cast iron and steel. It was first necessary to secure proficiency in the proper treatment of the metal and the application and fusion of the ground coats and enamel. A number of excellent undercoatings and enamels have been developed, both for cast iron and steel. A study of enamels possessing maximum resistance to solution is under way.

Silica Brick.

An extensive study is under way of the several quartzite rocks used for the manufacture of silica brick. This investigation deals with the expansion in volume which the materials undergo in firing, the change in specific gravity, and the crystalline transformation of the quartz to cristobalite and tridymite, determined by the microscopic examination.

Effect of Fused Slag Upon Fire Bricks.

At the request of an engineering firm, a number of fire bricks of different makes have been subjected to the action of molten slag at a temperature of 1,400° C. The slag was of the composition of one which had seriously corroded fire bricks of various kinds. The tests made succeeded in pointing out the brand of fire bricks most resistant to the slag action.

Effect of Pressure Upon Fire Bricks at Furnace Temperatures.

In cooperation with the American Gas Institute and the American Refractories Manufacturers' Association, tests have been carried on for the purpose of correlating the effect of varying pressures upon clay fire bricks at the temperatures 1,300° and 1,350° C. The results obtained have been made the basis of tentative specifications to be adopted by the Gas Institute.

Strength of Brick Piers.

The investigation of the strength of large brick piers, which has been conducted during the previous two years, has been confined to brick selected from the important geographical districts east of the Mississippi. The bricks have been classified individually according to the tentative standards recommended by the American Society for Testing Materials. The experimental work of this investigation has been completed for piers constructed from the product of the Chicago and Pittsburgh districts. The work will be continued for the remaining districts during the coming year. This research is being carried on in cooperation with the National Brick Manufacturers' Association.

Strength of Hollow Building Tile.

During previous years, numerous tests of building tiles from different geographical districts have been made and the data is being studied and coordinated for publication. In addition, a number of tile walls have been tested under compression and transverse forces to determine the physical laws and most efficient types of construction, appropriate mortars, best type of bond, the relation of strength to hardness of burn, etc. This investigation will be continued during the coming year. It is hoped ultimately to furnish adequate data for outlining standard methods of testing tile and preparing consistent specifications for the use of manufacturers and engineers.

Resisting Power of Earths.

The investigation of the resisting power of earths is being conducted in cooperation with a committee of the American Society of Civil Engineers, and a large number of tests have already been made

to determine the best means of testing earths under standard conditions. A study of the data thus far obtained has shown the need of some modification of apparatus, and this has been effected with good results. The general laws of earths subject to stress and strain have already been definitely formulated in mathematical physics, but to obtain determinate solutions of the equations for application to engineering practice, it is necessary to know the elastic coefficients of actual earths. In the experimentation being conducted, the endeavor is made to supply these coefficients and their range of possible variation to a closer degree of precision than has been obtained heretofore. A number of experiments have also been carried out with good results to determine the laws of variation of frictional coefficients in relation to diameter, and perimeter of piles and foundations as preliminary to further tests on a larger scale.

Clay Tests.

Approximately 500 tests of clays have been made for State geological surveys and private individuals, especially with reference to finding new sources of kaolins and paper clays. Special attention has been paid to southern clay deposits for the purpose of encouraging their development. Thus clays have been found in Florida suitable for the manufacture of turpentine cups, new deposits of ball clays in Alabama, fire clays in Mississippi and Arkansas, and vitrifying clays in other States of the South. The excellent qualities of the Florida and Georgia kaolins have been confirmed and their more extensive use advocated.

Cooperation is being carried on with exploration work in North Carolina for the purpose of assisting in locating new deposits of the excellent kaolins of the Appalachian districts.

During the year the Pittsburgh branch of the Bureau made nearly 600 physical and chemical tests of clay products for the public.

Tests of Clay Products for the Government.

Tests of fire bricks, paving and building bricks, porcelain, etc., are being conducted by the Bureau for the Supervising Architect, the Panama Canal, the Bureau of Foreign and Domestic Commerce, and other Government departments. Physical and chemical tests of clay products made for the various branches of the Government during the year amounted to 298; these were made at the Pittsburgh branch.

Industrial Cooperation and Dissemination of Technical Information in Regard to Clay Products.

Cooperation is carried on by the Bureau with many concerns and individuals regarding industrial problems, both by correspondence and consultation. This work is continually becoming heavier. Extensive cooperation is maintained also with a number of technical societies, such as the National Brick Manufacturers' Association, with whose aid a large number of brick piers are being tested; the National Hollow Tile Manufacturers' Association; the National Terra Cotta Society; the American Refractories Manufacturers' Association; the Vitrified Clay Products Manufacturers' Association; the American Gas Institute, etc. The Bureau assisted also in conduct-

ing short industrial courses in clay working at the University of Illinois, Iowa State College, the New York State School of Ceramics, and Rutgers College.

Investigation of Lubricating Oils.

Considerable work has been done in developing the test for demulsibility, or resistance to emulsification, referred to on page 138 of the annual report for 1914. The design of the apparatus has been improved and a new apparatus constructed in the Bureau shops which has given complete satisfaction. It has been found that the paddle dimensions of the emulsifier may be varied within considerable limits without affecting the value obtained for demulsibility, so that no calibration of the instrument is required. The investigation has been extended to include used as well as unused oils, and interesting results have been obtained in regard to the decrease of demulsibility with use. It is believed that power-house engineers, by the use of this apparatus and method of test, could obtain valuable information in regard to the rate of deterioration of oil in use in their plants.

The test has proved of much service in selecting engine oils from samples submitted by contractors under competitive bid. During the past year engine oils selected mainly on account of their high demulsibility have been in use in the Government power plants in the District of Columbia, and no complaints have been received in regard to the quality of these oils. This test, in combination with chemical tests previously in use, has made it possible to write specifications for four oils for the General Supply Committee. Contracts under these specifications are now in force.

Preliminary descriptions of the test for demulsibility have been published in Power, April 4, 1916, page 485; The Oil, Paint and Drug Reporter, April 17, 1916, page 36 R; and in a paper presented before the American Society for Testing Materials at Atlantic City, June 30, 1916. Data on the relation between demulsibility and carbonization is given in Bureau Technologic Paper No. 73. A publication is being prepared which will give a more complete account of experience with the test for demulsibility.

Information Regarding Lubricating Oils.

The Bureau is frequently called upon by the different Government departments and other large consumers of lubricating oils to give advice in regard to writing specifications. This service has been rendered by the Bureau for the past two years, during which time the requirements of different Government power plants have been carefully studied. During April of the present calendar year the Bureau's oil engineer, by request, addressed the Independent Oil Men's Association, in New York City, on the lubricating value of oils.

Experimental Rubber Plant.

The Bureau's equipment includes machinery and apparatus for compounding and vulcanizing rubber, together with a testing room in which the temperature is automatically regulated, containing numerous testing machines that have been developed at the Bureau to meet the demands of routine tests and special work of investiga-

tion. During the past year 150 pounds of crude rubber, of four different varieties, was washed and dried, and 59 rubber compounds were mixed and vulcanized for various purposes. A number of special compounds were made for the use of the chemical division in checking methods of chemical analysis. Tests on some of these compounds resulted in the preparation of a method for determining barium carbonate and sulphate in vulcanized rubber goods, which has been published as Technologic Paper No. 64. Other compounds were made into tubing of various sizes for experimental use in different laboratories of the Bureau.

In the manufacture of rubber goods oil substitutes are being used in constantly increasing quantities, and their effect on the quality and life of the rubber articles made from such compounds is not very well understood. A number of compounds containing oil substitutes were prepared for the purpose of studying their chemical and physical properties, but much work remains to be done before the Bureau will be in a position to draw any definite conclusions.

The Bureau is experimenting with a number of rubber compounds that have been made into eye shades for use in connection with the range finders on battleships. A number of these shades have been molded in the Bureau's experimental rubber laboratory and are being tested in service with the view of ascertaining the compound best suited for such use.

The Bureau's experimental plant has been used to some extent in cooperative work with manufacturers and technical societies in developing specifications for rubber goods and standard methods of testing.

Physical Properties of Rubber.

The investigation of the physical properties of rubber has been greatly handicapped during the past year by the steadily increasing pressure of routine work on the laboratory's limited force.

Progress has been made in studying the effect of dry heat on rubber stationery bands and rubber insulation of wire, the object being to establish a relation between the effect of dry heat as an accelerated test as compared with the effect of aging under normal atmospheric conditions. The Bureau will soon be prepared to draw up specifications for the purchase of rubber bands by the various Government departments.

During the past six years the Bureau has been actively engaged in the development of improved methods of testing the physical properties of rubber. Investigations along this line have resulted in the development of numerous special testing machines which were designed to facilitate the testing of rubber according to specifications in general use.

The Bureau has received numerous requests from manufacturers and large consumers of rubber for information relative to methods of testing and for detailed drawings of these machines which have been installed in many laboratories with gratifying results.

Specifications for Rubber Goods.

The preparation of standard specifications for rubber and the methods of testing form a very important part of the work of the Bureau, in which the physical testing and chemical laboratories co-

operate. When called upon the Bureau acts as adviser concerning the quality of material best suited to the needs of the various Government offices. In connection with this line of work, representatives from about 20 bureaus and offices met at the Bureau in October, 1915, to consider the question of standardization of specifications, methods of physical and chemical testing, etc. It is believed that this conference and others which are to follow will result in the establishment of uniformity in Government specifications, as far as the needs of the service will permit of such standardization.

"Friction" Testing Machine.

In the manufacture of pneumatic tires, rubber belting, rubber hose, etc., the value of the finished product depends in a large measure upon the "friction" or adhesion between adjacent plies of fabric, which are impregnated with rubber. As a result of the Bureau's work for several years past, an autographic machine has been designed for testing "friction." A diagram that is made automatically during the test shows the exact value of the adhesion between adjacent layers of fabric at all points. This machine, which was constructed in the Bureau's instrument shop, has proved very satisfactory, and by its use the testing of a large number of samples has been greatly facilitated. The results of tests by the present method are more instructive than those formerly obtained, since the autographic machine shows the uniformity of the "frictioning" as well as the average adhesion over a given length. Working drawings of the machine have been furnished by request to two manufacturers of testing machines and to several manufacturers of rubber goods. An illustrated description of the machine appeared in the May issue of the India Rubber World.

Rubber-Insulated Wire.

The Bureau is cooperating with a number of testing laboratories identified with the American Society for Testing Materials in investigating the merits of an accelerated heat test as applied to rubber insulation of wire. The object of the work is to determine the relative effect of dry heat at 160° F., as compared with the effect of natural aging under uniform atmospheric conditions. This investigation is in line with a similar work that has been in progress at the Bureau for several years, in which the relative effect of dry heat, as compared with natural aging, has been studied in the case of 55 rubber compounds. Some of these results appear in the third edition of Bureau of Standards Circular No. 38, Testing of Mechanical Rubber Goods.

Test of Fire Hose for Government Departments.

For several years past the Bureau has tested rubber-lined fire hose for the District of Columbia Fire Department. This hose is purchased under competitive bid, according to specifications that have been revised by the Bureau of Standards, with the result that a saving of about $25,000 has been effected during the past two years without lowering in any way the standard of quality or efficiency of the hose purchased.

A similar service was rendered in the testing of 1,000 feet of unlined linen hose for use in connection with the State, War, and Navy Building.

Window-Sash Cord.

The Bureau is frequently called upon to test the wearing quality of window-sash cord. To carry out this work there has been in use for several years a special testing machine which was designed by the Bureau to duplicate as far as possible the actual conditions of service. The results obtained in testing a variety of sash cord prove that the wearing quality of a cord is, within wide limits, quite independent of its tensile strength, but is dependent in a remarkable fashion upon oils, greases, and other substances which are naturally present or are added by design. Thus it was very interesting to discover that the life of an apparently dry cord could be reduced to 2 per cent of its original value by merely extracting the lubricating substances present, the fiber of the cord remaining in the meantime quite uninjured.

Wearing Quality of Sole Leather.

The testing of sole leather to determine its wearing quality is a problem that has been brought to the Bureau's attention a number of times by Government departments and by manufacturers. Appreciating the importance of the problem, and in the absence of an adequate test for this property of leather, the Bureau has given the subject careful consideration, with the result that a testing machine has been designed, with which it is proposed to conduct a series of experiments, with the view of establishing a standard method of testing sole leather. A number of prominent manufacturers have expressed their willingness to cooperate with the Bureau in this important work.

Investigation and Tests of Shot Lines for the United States Coast Guard.

In the last annual report attention was called to tests of unusual importance in connection with the purchase of flax shot lines for the United States Coast Guard. A similar service has been rendered by the Bureau during the past year, when 63 samples, representing 38,400 yards, of shot line were tested, with the gratifying result that only about 20 per cent of the material was rejected for noncompliance with specifications as compared with about 50 per cent of rejections during the previous year.

Information Furnished on Physical Tests of Rubber.

During the past year numerous requests have been received for information relative to special apparatus and methods of testing the physical properties of rubber that have been developed by the Bureau. Such requests, which come from Government departments, manufacturers, and individuals, may usually be answered by reference to the third edition of Circular No. 38, Testing of Mechanical Rubber Goods.

Tests of Miscellaneous Materials.

A total of 1,230 miscellaneous samples were tested during the past year. In addition to the large number of special tests carried out in connection with investigations the following routine tests were made during the fiscal year: One hundred and fifty-two samples of rubber

hose, such as air, air-brake, fire, suction, water, etc.; 205 samples of packing, consisting of asbestos, rubber, etc.; 22 samples of rubber bands; 137 samples of rubber-covered wire and cable; 81 samples of hack-saw blades; 99 samples of belting, consisting of leather and rubber; 81 samples of rope; 331 samples of lubricating oils; and smaller quantities of numerous other materials. The bulk of this work was done for the Panama Canal and for the General Supply Committee, although quite a large proportion of the samples were tested for various Government departments and for manufacturers who desired to avail themselves of the special facilities offered by the Bureau.

Identification of Textile Fibers.

An important phase of the textile work of the Bureau is the microscopical examination of fibers for the purpose of determining their identity. A great deal of information may be obtained about the probable service of a material if the fiber from which it is made is known. Adequate methods of microscopical analysis will also greatly assist in preventing misstatements of fiber content intended to deceive the purchaser as to the quality of a material.

Measurement of Length of Yarns.

Owing to the elastic nature of yarns, it is difficult to determine their true length, the tension necessary to produce straightness being also sufficient to increase the normal length. Methods have been devised for computing the normal length of yarns from a series of measurements under various tensions. The tension necessary to produce this length may then be applied to all yarns of the same character and the length measured with a relatively small error. This procedure was found particularly advantageous in determining the percentage of crimp in the yarns in fabrics used for making automobile tires. A description of the method is given in a paper now being prepared.

Standardization of Tensile-Strength Testing Methods.

There has been a considerable variation in the practice of making tests for tensile strength upon fabrics. Differences have existed in regard to the methods of sampling, the dimensions of the test specimen, and the method and rate of application of load. Investigations are now being made to determine the best procedure from the point of view of accuracy and reliability as well as convenience. This will enable the adoption of a single method, making possible a direct comparison of the results obtained in different laboratories.

Moisture in Textile Materials.

The physical properties of textile materials are appreciably affected by the amount of moisture contained. It is therefore fundamentally important to be able to determine and control this moisture in order to avoid misinterpretation of the results of other investigations. A new apparatus has been designed and constructed by the Bureau, and it will be employed in making a careful and thorough study of all the various phases of this important problem.

Investigation of Cement-Bag Fabric.

In cooperation with the various cement, lime, and gypsum associations, the Bureau is making an extensive investigation of the fabric used in the manufacture of cement bags. The tests will include a determination of the weight, threads per inch, tensile strength, and elongation at breaking stress. This work is also being carried on in cooperation with the textile committee of the American Society for Testing Materials. The results of this research will be very helpful in deciding certain methods for testing purposes and will greatly assist in drafting specifications for bag fabric in general.

Comparative Durability Tests Upon Cotton and Wool Flag Bunting.

During the past two years cotton bunting has been employed in large quantities in the manufacture of flags. This cotton bunting is sold at about one-half the price of wool bunting. It has, therefore, replaced the wool flag in many instances in Government and other purchases. A very comprehensive series of tests are now being made upon cotton and wool flags as to their relative durability to exposure to weather, fastness of color, tensile strength, etc. This investigation is also being made upon buntings of different constructions of yarn, twist, and weight.

Folding Durability of Cotton Yarns for Automobile-Tire Fabric.

The manufacturers of automobile tires are constantly endeavoring to prolong the life and durability of their tires. The length of time that tires will continue in service depends largely upon the kind and quality of the fiber, the care exercised in the manufacture of the single yarns, and the construction of the ply or finished yarns. Objection has been made to the use of Sakellarides cotton in the manufacture of tire fabrics because of its reputed brittleness or lack of ability to withstand folding. To ascertain whether there was foundation for this objection a preliminary series of tests was made at the Bureau of Standards upon several samples of yarns made from various kinds of cotton. These yarns were approximately of the size No. 23/11 and were made from sea-island, Egyptian, Sakellarides, and Peelar cotton. Other physical tests were made in order to better compare the results obtained from tests of the different yarns examined. The results of this investigation show that the folding endurance is not less in the case of Sakellarides than in the cases of the other varieties of cotton tested.

Textile Conference.

A conference was held at this Bureau in January, 1916, to consider and discuss "methods of making tests upon textile materials, misbranding and misrepresentation of textiles, and results of investigational and research work." There were in attendance about 60 representatives of various mills, dealers, Government departments, and others.

Information Furnished on Textile Subjects.

A great many requests come to the Bureau for information regarding the testing and properties of various textile materials. These

inquiries are often suggestive of new phases of textile research which should be carefully studied.

The various Government departments need specifications for regulating their purchases and this Bureau has actively assisted in writing such specifications in many instances.

The requests from the general public include inquiries regarding methods of identifying fibers, determining the amount of loading material, testing the tensile strength, elongation under breaking load, and the dimensions and weights of all kinds of materials. Laboratories and testing houses frequently ask for suggestions as to the best equipment to purchase.

Textile Testing.

The Bureau has tested the following samples of textiles during the past year: For the Government departments, 3,034 samples; for public and private interests, 121 samples; making a total number of 3,155 samples tested.

In investigational work and cooperative testing with various mills, more than 500 samples were tested which were not considered of the usual routine nature and are, therefore, not included in the above number of routine tests. The actual number of individual tests performed upon these 3.655 samples made a total of more than 35,000.

Publications on Textile Subjects.

New publications issued on textile subjects during the year are: Technologic Paper No. 68, Standardization of Automobile Tire Fabric Testing; Technologic Paper No. 57, Difference in Weight between Raw and Clean Wools; and Circular No. 41, The Testing and Properties of Textile Materials. The latter is the second edition and gives a description of the methods of routine testing now employed in the textile laboratory.

Manufacture of Filter Paper.

Filter paper is used in all chemical laboratories and in large quantities in industrial work for filtering out fine suspended particles from a liquid. The highest quality of filter paper is imported, and due to present conditions abroad it is almost impossible to obtain it. Many inquiries have been received at this Bureau asking if it was possible to obtain domestic filter papers of suitable quality. None is made in this country and, therefore, an investigation as to its manufacture has been started at this Bureau. Samples of the best grades of imported papers have been obtained and they are being subjected to a series of tests to determine their physical and chemical properties. The Bureau has also succeeded in interesting several paper manufacturers in this grade of paper, and the work so far accomplished indicates that it will be possible to produce a domestic paper that will equal in every respect the best imported filter paper.

Filter papers must have a very low percentage of ash, a rapid rate of filtering, and must be free of certain constituents. The chemical treatment after manufacture is highly important and so far this final chemical treatment has not been satisfactorily worked out. It is proposed to continue the investigation along this line, since the final chemical treatment determines the quality of the paper.

Paper Bags for Shipping Cement, Lime, and Gypsum.

At the request of the Association of American Portland Cement Manufacturers, National Lime Manufacturers Association, Gypsum Industries Association (Inc.), and the Eastern Railroad Classification Committee, this Bureau has taken up the question of the preparation of standard specifications and methods of testing paper for use in making paper bags. These paper bags are to be used in place of the usual cotton bag for shipments of cement, lime, and gypsum. The cotton bag is not entirely satisfactory, due to its cost, and because of the necessity of returning all bags to the manufacturer. Bags not returned are charged against the user of the material, thereby entailing additional expense. All paper bags are not suitable, and it is proposed, therefore, to determine the needs of these industries, so that the most suitable paper may be secured. This work will progress as fast as the facilities of the paper section will permit.

Utilization of Domestic Clays in the Paper Industry.

The paper industry is a large user of clay, both as a filler and for high-grade coated paper. The best clays used for this purpose have been imported from England, though there are many clay deposits in this country which are of high grade. It is proposed, therefore, to investigate several of the best imported clays in their relation to the needs of the paper industry and with the information so obtained make a careful examination of the domestic clays for the purpose of securing a satisfactory domestic clay to replace that imported.

Paper-Testing Devices.

The necessity for standard methods of testing materials is being felt in the paper industry, and a demand has been created for testing devices the results of which may be interpreted in terms of the quality of a paper to be used for a particular purpose. The testing devices now in use are not entirely satisfactory, as they are of the empirical type. Data from a series of comparative tests, using several of the well-known testing devices, have been secured and are now being compiled. Certain changes are also being made in these testing devices, as a result of a study of some of the more common faults found. The results of this investigation will place the testing of paper on a firmer basis and provide means for securing more accurate data relating to the quality of a particular paper.

Utilization of Waste Paper for Remanufacture into Paper.

This country has recently seen an unprecedented rise in the cost of all grades of paper, caused by unusual demands for paper and a shortage of many materials entering into the finished paper. This demand for paper and the lack of an adequate supply of raw material has forced many manufacturers to look to the use of waste paper for an additional supply. The processes now in use for the recovery of waste paper are very wasteful; therefore, for this reason and because of the possibilities involved, it is hoped to be able to make a study during the coming year of methods of cooking and treating old papers.

Casein and its Application to the Paper Industry.

Casein is an important substance found in milk, and like many other organic substances has a wide variety of uses, such as for artificial ivory, for paints, as an adhesive, and many other industrial uses. Its application in the paper industry is as an adhesive to bind a thin film of clay to the surface of a sheet of paper. Such paper is known as a coated paper and is suitable for the reproduction of photographs where great detail is essential.

This casein investigation was started at the request of the Dairy Division of the Bureau of Animal Industry, Department of Agriculture, and is a joint investigation with it. Its end of the problem has been a study of the production of skim milk and buttermilk caseins, while the application of casein in the paper industry is being developed by the Bureau of Standards.

At the present time the best caseins are imported. The domestic caseins are inferior in color, adhesiveness, solubility, and uniformity of product, and any investigation tending to improve the domestic product will not only help to make American industries more independent of the imported supply, but will also help to develop a domestic product.

The particular purpose of the investigation is to establish the most suitable methods for the production of skim-milk and buttermilk caseins, devise methods of testing the finished product, and study the best methods for its use in the paper industry.

Paper Testing.

During the past year the Bureau has tested the following samples of paper: For the Government Printing Office and the Government departments, 3,518; for public and private interests, 80; making the total number of samples tested 3,598. This total number is a slight decrease from last year, as there were no four-year contracts for paper this year as there were last year.

Information Furnished on Paper.

The Bureau has been called upon by the several departments and other branches of the Government service to assist in the preparation of definite specifications covering many general needs, and also for specifications for paper for special uses. Work of this kind is continuous, as each year changes are made to meet the growing needs of the service. Continuous expert assistance of this kind is rendered to the Congressional Joint Committee on Printing, the General Supply Committee, and the Post Office Department.

The inquiries received requesting information relative to the pulp and paper industry have covered the widest possible range. Such inquiries have dealt not only with all phases of the testing of paper and pulp, but also with many phases of the manufacturing end of the industry.

The following list includes some of the more important inquiries received, as well as others noted, to show something of the range of these inquiries:

(1) Report to one of the central western universities covering a series of tests on 25 samples of commercial bond papers, which brought out the fact that some of the lower priced papers were among the highest in quality.

(2) Report on the causes of deterioration of the adhesive used in making certain envelopes supplied to the Government service; also suggestions by which an envelope manufacturer was enabled to overcome this difficulty. The Bureau always endeavors to offer its assistance to a manufacturer who is having trouble with his Government deliveries, as it is the belief that any assistance to a Government contractor tending to improve his deliveries to the Government will also have a beneficial effect on his product when sold to the commercial trade.

(3) Requests for standard samples and specifications and also many special papers of all kinds have been received, with the request that a specification for their purchase be prepared. Inquiries of this kind have covered the entire range of kinds and grades of papers.

(4) Information and assistance have been rendered in answer to inquiries on many subjects concerning paper. Some of these inquiries have resulted in investigations of considerable extent. Such questions as the manufacture of filter paper, photographic paper, blueprint paper, parchment paper, and dialyzing paper have been handled.

Attention has also been given to the utilization of certain waste materials, due to the large number of such inquiries continually being received.

Many visitors have visited the paper laboratory, showing a general awakening on the part of both the user and producer of paper to the need for definite paper specification.

During the past year the list of visitors included many chief chemists and engineers from large manufacturing establishments. In a number of cases these representatives have come prepared to study our methods of testing and have spent from one to two weeks working in the paper laboratory. Assistance of this kind is always gladly rendered and interested parties are given every opportunity to become acquainted with the Bureau's methods of testing.

III. OFFICE, AND ENGINEERING AND CONSTRUCTION.

1. OFFICE.

Publications.

During the fiscal year just ended the Bureau issued 77 publications, of which 70 were new and the remainder revised editions. Approximately 63 publications were reprinted, owing to the pressing demand. The new publications included five numbers of the Bulletin of the Bureau of Standards, which completes the twelfth volume of the scientific papers. There were also issued 34 new scientific papers, 28 new technologic papers, 5 new circulars, and 3 new miscellaneous publications.

The following new circulars were issued during the year: Regulation of Electrotyping Solutions, Measurements for the Household, United States Standard Tables for Petroleum Oils, Invar and Related Nickel Steels, and United States Standard Baumé Hydrometer Scales.

The following scientific papers were issued: An Aneroid Calorimeter; Specific Heat and Heat of Fusion of Ice; The Emissivity of Metals and Oxides.—IV. Iron Oxide; Characteristics of Radiation Pyrometers; Interference Measurements of Wave Lengths in the Iron Spectrum (2851–3701), with Notes on Comparisons of Lengths of Light Waves by Interference Methods, and Some Wave Lengths in the Spectrum of Neon Gas; Effective Resistance and Inductance of Iron and Bimetallic Wires; A Direct-Reading Device for Use in Computing Characteristics of Vacuum Tungsten Lamps; A Study of the Quality of Platinum Ware; Calculation of the Maximum Force Between Two Coaxial Circular Currents; Construction of Primary Mercurial Resistance Standards; Note on the Resistance of Radiotelegraphic Antennas; A Method of Measuring Earth Resistivity; A New Relation Derived from Planck's Law; Center of Gravity and Effective Wave Length of Transmission of Pyrometer Color Screens and the Extrapolation of the High Temperature Scale; Studies of Instruments for Measuring Radiant Energy in Absolute Value: An Absolute Thermopile; Present Status of the Determination of the Constant of Total Radiation from a Black Body; Illumination from a Radiating Disk; Photometry of the Gas-Filled Lamp; Life Testing of Incandescent Lamps at the Bureau of Standards; Preparation of Pure Iron and Iron-Carbon Alloys; Colorimetric Determination of Acetylene and Its Application to the Determination of Water; Constants of the Quartz-Wedge Saccharimeter and the Specific Rotation of Sucrose.—1. The Constants for the 26-Gram Normal Weight; Effect of Imperfect Dielectrics in the Field of a Radiotelegraphic Antenna; Luminosity of a Black Body and Temperature; Inclusions in the Silver Voltameter Deposits; Correlation

of the Magnetic and Mechanical Properties of Steel; General Design of Critically Damped Galvanometers; Interference Measurements of Wave Lengths in the Iron Spectrum (3233A–6750A); Relation Between Composition and Density of Aqueous Solutions of Copper Sulphate and Sulphuric Acid; Protected Thermoelements; An Interlaboratory Photometric Comparison of Glass Screens and of Tungsten Lamps, Involving Color Differences; Investigations of the Laws of Plastic Flow; Distribution of Energy in the Visible Spectrum of an Acetylene Flame; and Further Experiments of Volatilization of Platinum.

The following technologic papers were issued: Investigation of the Durability of Cement Drain Tile in Alkali Soils; Value of the High-Pressure Steam Test of Portland Cements; An Air-Analyzer for Determining the Fineness of Portland Cement; Emergent Stem Correction for Thermometers in Creosote Oil Distillation Flasks; Viscosity of Porcelain Bodies High in Feldspar; Use of Sodium Salts in the Purification of Clays and in the Casting Process; Electrolysis and Its Mitigation; An Investigation of Fusible Tin Boiler Plugs; Special Studies in Electrolysis Mitigation, No. 3.—A Report on Conditions in Springfield, Ohio, with insulated Feeder System Installed; Special Studies in Electrolysis Mitigation.—IV. A Preliminary Report on Electrolysis Mitigation in Elyria, Ohio, with Recommendation for Mitigation; Protection of Life and Property Against Lightning; Difference in Weight Between Raw and Clean Wools; Compressive Strength of Portland Cement Mortars and Concretes; Standard Test Specimens of Zinc Bronze.—1. Preparation and Specifications. 2. Microstructure; Microstructural Changes Accompanying the Annealing of Bronze (Cu 88, Sn 10, Zn 2); Some Foreign Specifications for Railway Materials; Modern Practice in the Construction and Maintenance of Rail Joints and Bonds in Electric Railways; Determination of Barium Carbonate and Barium Sulphate in Vulcanized Rubber Goods; Determination of Oil and Resin in Varnish; Detection of Resin in Drier; Some Qualitative Tests for Gum Arabic and Its Quantitative Determination; Standardization of Automobile Tire Fabric Testing; Determination of Carbon in Steels and Irons by Direct Combustion in Oxygen at High Temperatures; Effect of Certain Pigments on Linseed Oil; Data on the Oxidation of Automobile Cylinder Oils; and Determination of Volatile Thinner in Oil Varnish.

The following miscellaneous publications were issued: Annual Report of the Director for the Fiscal Year Ended June 30, 1915; Tenth Annual Conference on Weights and Measures of the United States: and Tolerances and Specifications for Weights and Measures, 1915.

Technical Library.

The library contains 14,460 accessioned volumes, all of a scientific and technical character with the exception of a few law books; 333 technical and scientific periodicals currently received, 219 in English, 114 in other languages.

Personnel.

During the year the Bureau staff comprised 239 statutory appointees, and about 176 engaged in researches and investigations specially authorized by Congress. The statutory positions included 145 scientific positions, 32 office assistants, 39 engaged in the operation of the plant, and 23 in the construction. There were 436 personnel changes during the year. These included 114 separations from the Bureau, of which 60 were resignations.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1916, 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, 1916:

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$298,780.00	$271,503.80	$11,626.46	$15,649.74
Equipment	50,000.00	28,630.89	21,284.28	84.83
General expenses	27,000.00	22,304.24	4,587.17	108.59
Repairs and alterations	2,000.00	1,812.78	187.13	.09
Grounds	6,000.00	5,117.71	875.88	6.41
High-potential investigation	15,000.00	13,643.35	1,315.77	40.88
Refrigeration constants	15,000.00	13,903.43	1,093.72	2.85
Testing structural materials	100,000.00	92,018.48	7,960.34	21.18
Testing machines	30,000.00	26,527.50	3,404.12	68.38
Investigation of fire-resisting properties	25,000.00	21,105.21	3,718.34	176.45
Public-utility standards	25,000.00	22,908.31	2,055.19	36.50
Railway materials	15,000.00	11,465.10	3,534.90	.....
Testing miscellaneous materials	20,000.00	17,399.06	2,600.50	.44
Radio research	[a] 12,263.74	7,709.58	4,542.48	11.68
Testing railroad scales	40,000.00	23,993.67	16,006.33	.....
Heating system, north laboratory	3,000.00	2,095.35	838.22	66.43
Current-meter testing tank	3,000.00	2,998.34	.....	1.66
Equipping chemical laboratory building	35,000.00	60.92	17,862.74	17,076.34
Warehouse and storehouse	45,000.00	44,808.00	191.07	.93
Chemical laboratory	200,000.00	110,154.89	87,811.45	2,033.66
Total	967,043.74	740,160.61	191,496.09	35,387.04

[a] Includes reimbursement of $2,263.74.

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1916:

FISCAL YEAR 1914.

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$290,940.00	$270,123.88	.....	$20,816.12
Equipment	[a] 59,075.00	58,761.10	$129.70	184.20
Repairs and alterations	2,000.00	2,000.00	.....	.....
General expenses	27,000.00	25,582.39	181.47	1,236.14
Grounds	3,000.00	2,997.53	.....	2.47
Testing structural materials	75,000.00	74,620.49	.....	379.51
Testing machines	30,000.00	29,913.22	83.92	2.86
High potentials	15,000.00	14,963.71	4.10	32.19
Refrigeration constants	15,000.00	14,647.50	269.40	83.10
Testing railroad scales	25,000.00	24,943.70	.80	55.50
Fire-resisting properties	25,000.00	23,640.93	438.70	920.37
Total	567,015.00	542,194.45	1,108.09	23,712.46

[a] Includes reimbursement of $9,075.

FISCAL YEAR 1915.

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$293,500.00	$278,389.16	.....	$15,110.84
Equipment	[a] 57,311.33	55,037.79	$1,741.64	531.90
Repairs and alterations	2,000.00	1,998.52	.....	1.48
General expenses	27,000.00	24,963.37	1,470.38	566.25
Grounds	6,000.00	5,998.74	.....	1.26
Testing structural materials	100,000.00	99,703.50	136.92	159.58
Testing machines	30,000.00	29,853.15	117.02	29.83
High potentials	15,000.00	14,984.96	.....	15.04
Refrigeration constants	15,000.00	14,997.89	.....	2.11
Testing railroad scales	40,000.00	38,821.07	1,178.93	.....
Fire-resisting properties	25,000.00	24,637.57	344.08	18.35
Testing miscellaneous materials	20,000.00	19,909.70	11.53	78.77
Railway materials	15,000.00	14,839.06	112.42	48.52
Public-utility standards	25,000.00	22,930.19	1,741.52	328.29
Total	670,811.33	647,064.67	6,854.44	16,892.22

[a] Includes reimbursement of $7,311.33.

Statement of Tests.

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. It involves, primarily, the investigation of the scientific principles underlying the tests, the study 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 1916 the Bureau made 217,442 tests and inspected 1,290,590 incandescent lamps at various factories for other departments of the Government. Of the total tests, 207,892 were for the Government and 9,550 for the public. The testing was distributed as follows, according to the nature of the tests: Length measures, 453; mass, 3,524; capacity 1,837; temperature, 12,685; hydrometry, 651; miscellaneous, 180; optical, 2,416; time, 23; electrical, 829; photometry, 3,365; chemical 7,824; engineering (miscellaneous), 465; engineering (instruments), 294; structural materials, 173,644; paper and textile, 7,653; metallurgical, 1,599. The estimated fees amount to $154,077.20, of which $13,674.17 was collected on account of tests for the public. The fees noted for Government tests are included merely for comparison purposes, as no charge is made for tests performed for the National or State governments.

NUMBER AND VALUE OF TESTS COMPLETED, FISCAL YEAR ENDED JUNE 30, 1916.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length	285	$567.99	168	$455.61	453	$1,023.60
Mass	2,070	8,873.15	1,454	610.35	3,524	9,483.50
Capacity	1,281	608.15	556	427.90	1,837	1,036.05
Optical	2,248	1,671.00	168	307.50	2,416	1,978.50
Hydrometry	510	517.50	141	256.75	651	774.25
Miscellaneous	176	301.25	4	15.00	180	316.25
Time	3	24.50	20	92.50	23	117.00
Temperature	8,279	1,869.31	4,406	2,783.22	12,685	4,652.53
Electrical	313	2,203.13	516	2,672.09	829	4,875.22
Photometry [a]	3,056	11,081.00	309	522.40	3,365	11,603.40
Chemical [b]	6,665	47,952.20	1,159	3,495.65	7,824	51,447.85
Physical and mechanical tests:						
Engineering, miscellaneous	455	1,685.00	10	35.50	465	1,720.50
Engineering, instruments	257	1,282.00	37	220.00	294	1,502.00
Structural materials	173,216	44,469.00	428	1,366.50	173,644	45,835.50
Paper and textiles	7,487	12,116.75	166	339.75	7,653	12,456.50
Metallurgical	1,591	5,181.10	8	73.45	1,599	5,254.55
Total	207,892	140,403.03	9,550	13,674.17	217,442	154,077.20

[a] In addition, the Bureau inspected 1,290,590 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $6,452.95 additional.
[b] Of these tests, 4,519, amounting to $34,821.20, were chemical tests made on structural materials.

2. ENGINEERING AND CONSTRUCTION.

Chemical Laboratory.

The contract for constructing the chemistry building having been awarded to Wells Brothers Co., of New York, the first sod was turned on September 13, 1915, in the presence of the Director of the Bureau and most of the chemistry staff. On March 23, 1916, the corner stone was laid by the Secretary of Commerce with appropriate ceremonies. It is expected that the building will be completed in September of this year, so far as the present contract is concerned. Bids have been received for most of the plumbing and equipment that can be installed under the specific appropriation provided by Congress for these purposes. Only about one-half of the space in the building can be equipped at present.

IV. RECOMMENDATIONS.

Increase in Scientific Staff.

For the past three years there has been practically no increase in the statutory positions of the scientific staff. In the meantime, the calls upon the Bureau in connection with the scientific work of the country, and especially the industries, have grown by leaps and bounds. The Bureau is not only neglecting much work that should be done, but has been compelled to do many things in a temporary and superficial manner. This has been especially true during the past two years; nevertheless, every effort has been made to utilize the resources of the Bureau to the greatest possible extent in assisting the public to meet these new conditions. The demand on the part of the industries for accurate and reliable scientific data has never been as great or as important as at present. This demand is a rapidly increasing one. A conservative estimate for the additional assistance needed has been prepared and will be submitted. This estimate has been based solely upon the most urgent and pressing needs of the Bureau and not for new fields of work. It is hoped that Congress will recognize the importance of this increase and provide accordingly.

Increases in Salaries.

Never has the demand for scientific and technically trained men been as great as at present. This has resulted in the loss of many well-trained men in the Bureau's staff. The time has come when some of the salaries paid such experts must be increased or their services dispensed with. This can not be done without a loss in quality and the deterioration of the high standard of the Bureau's work.

Additions in the Clerical, Operating, and Construction Staffs.

The clerical staff is entirely inadequate and should be increased to meet the present needs. This is especially true in the care of property, files, records, and correspondence.

The addition of the electrical building finished a year ago and the chemical building nearing completion makes it absolutely necessary to increase the operating force of the mechanical plant.

The testing and investigational work of the Bureau is greatly handicapped by the lack of sufficient instrument makers and mechanics. Estimates will be submitted for additional assistance of this kind.

Increases in Special Funds.

Increases are urgently needed in several of the special funds under which the Bureau is carrying on important work. The structural material fund is barely sufficient to care for the testing work of the

Government service. It should be increased by at least 50 per cent in order that the Bureau may undertake more investigational work needed by the Government service and by the public. The importance of this work can hardly be overestimated, not only from the standpoint of economy and efficiency in the structural work of the Government, but from that of the efficient and economical use of these materials on the part of the public.

The Bureau's work in connection with public utilities has proven of the utmost importance. The fund available is insufficient to cover more than two or three problems. The present appropriation might well be increased several fold; it would meet with the hearty approval of all public service and municipal bodies having to do with the regulation of public utilities. It would contribute greatly to better service on the part of public utilities, as well as to the conservation of life and property.

The enormous annual loss of property by fire emphasizes the great necessity for a better knowledge of the fire-resisting properties of materials and construction. To be of value, such work must be carried on with specimens commensurate with those used in practice. The Bureau's work in this direction has been well organized and much of the apparatus constructed. However, funds are needed for additional equipment as well as materials upon which to work, which in such cases are necessarily expensive; therefore, this fund should be increased by at least 50 per cent.

A small increase is needed in the fund for miscellaneous materials, due to the growing tendency on the part of the Government to buy such materials according to properly prepared specifications and tests.

During the past year the Bureau submitted an estimate to provide for the determination of physical constants, a part of which was approved by Congress. These constants are of the utmost value in scientific and industrial work. Their determination involves the most difficult work in physics and chemistry. The Bureau should ever be the source of accurate and authoritative values of this kind and ample provision should be made for their determination.

The funds available during the coming year for the investigation of mechanical appliances are not sufficient to meet even the needs of the Government service. Here again, as in the purchase of materials, the Government is purchasing machinery and all sorts of devices in accordance with carefully prepared specifications, and suitable tests are made before their acceptance. The standards of performance in such cases and the methods of measuring the same are equally important to the manufacturer and to the public. This fund should be increased to at least double its present value.

In general, it has been thought best to submit only such estimates as are urgently needed to care for present work rather than to enter new fields. However, two exceedingly important cases have arisen for which estimates will be submitted. The first is that of optical glass. Notwithstanding the importance of this material in the construction of all sorts of optical instruments, it has not yet been successfully manufactured in this country in any considerable quantity. Every effort should be made to assist in the development of this industry. Estimates will be submitted for a special fund intended to

enable the Bureau to undertake the important underlying scientific work needed in the production of optical glass.

The second case is that of electrodeposition of metals. Many industries are vitally concerned in the fundamental principles of the electrodeposition of metals, as, for example, the electrotyping and electroplating industries. Little attention has been paid to the underlying scientific principles involved. Such information is urgently needed; therefore, an estimate will be submitted for this purpose.

Buildings.

Attention is again directed to the urgent necessity of placing the structural material work of the Bureau in permanent quarters. An estimate for a suitable site, building, and additional equipment has several times been submitted, and it is earnestly hoped that favorable action will be taken during this coming year.

New Refrigerating Machine.

A new machine to produce the refrigeration needed in the laboratories is essential. The present machine was installed in 1904 and was well suited to the conditions then existing. The growth of the Bureau's work and the addition of several buildings make an increase of capacity imperative, while these and other conditions indicate marked economy to be obtained from a motor-driven compression machine instead of the present absorption type.

New Power Plant.

A new power-plant building has become an urgent necessity. The total boiler capacity of the present plant is already seriously overloaded, and the danger of operating with no reserve in case of breakdown is apparent. The electric generating units are in good condition, but should be moved to a new location to relieve the present congestion. Repairs can not now be made with requisite facility and many lines are inaccessible for repairs. Extension of switchboard space is impracticable in the present location, and for this reason much objectionable and unsafe construction has had to be permitted. The space vacated will be admirably suited to purposes of a general shipping and store room, which is also badly needed.

Respectfully,

S. W. Stratton, *Director.*

To Hon. William C. Redfield,
Secretary of Commerce.

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