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ANNUAL REPORT

OF THE

DIRECTOR
BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1915

WASHINGTON
GOVERNMENT PRINTING OFFICE
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CONTENTS.

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DIRECTOR, BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 1, 1915.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1915.

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, for the measurement of greater lengths, standards must be prepared which are multiples of the fundamental standard. This process of subdividing and multiplying the standard involves difficulties as great as those met with in the preparation of the fundamental standard itself.

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

to the large testing machine capable of measuring a load of thousands of tons. The complete range must be covered, which involves 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 question then arises, Why is it good or poor; what are the physical or chem-

ical 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 is even more important to the general public, and is 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 depend it is to be regretted that its force and equipment is 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, of quality or performance, involved in legislation or regulation pertaining to the public utilities. Many questions of disagreement between the public and utility companies as to these matters are referred to the Bureau for advice or adjustment, often avoiding unfair or inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. As far as possible such information is given in the form of publications upon definite subjects.

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

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

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

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

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

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

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

tigation, 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.

Weights and Balances.

Investigation of the constancy of analytical weights commonly used in chemical and physical laboratories have extended over a number of years. It has become increasingly certain that these weights are much less reliable than is generally assumed. Serious changes have been noted in many cases where there is known to have been no special cause for change.

Several high-grade precision balances have been investigated with special reference to the proper placing and alignment of the knife edges, and also as to the straightness of the knife edges and bearings. This preliminary work has given information on which it will be possible to base more intelligent study of these points with a view to establishing specifications and more satisfactory methods of testing these balances. Both makers and users of analytical and other high-grade balances are greatly in need of standard specifications and methods of testing these balances.

Plans for equipping the high-precision weighing room secured at the close of the preceding year were partially developed, but could not be completed because of the pressure of other work.

Of the 3,355 weights tested during the year, 1,884 were for cities, firms, individuals, etc., and 1,471 were for various branches of the Federal Government, the State governments, and State institutions.

The large number of tests for State governments show the continued interest in weights and measures inspection. The purchase by several of additional standards shows the expansion of the State work. This is especially noticeable in the case of apothecaries' and metric denominations.

Capacity and Length Measures.

There were tested during the year 70 capacity measures, including the standards of several States, and 362 length standards, of which 27 were tapes of the nickel-steel alloy. This alloy, because of its low coefficient of expansion, is being increasingly used for precise surveying operations.

An improved method for testing cubic-foot bottles has recently been developed which is more rapid than the usual method and the equipment required is less expensive. Instead of using a large and expensive balance for weighing first the empty bottle and then the bottles filled with water, use is made of Archimedes' principle in a very simple and comparatively inexpensive piece of apparatus. By this method one man can test a cubic-foot bottle in about twenty minutes, whereas the ordinary balance method requires two men about an hour. It is expected later to apply this method to the testing of large capacity measures.

Sieve Testing.

There were 225 standard sieves or pieces of wire cloth tested during the year. These included, besides the usual 100-mesh and 200-mesh sieves used in fineness determinations of cement, several sets of graded sieves for testing other materials. The pieces of wire cloth included a number of samples of bronze window-screen cloth for use in the Panama Canal Zone, of which measurements were made to determine whether the mesh and diameter of the wires conformed with the specifications.

Sieving screens are used in a large number of industries and there has been a considerable demand for a recognized standard screen scale in which the screens bear a simple and definite relation to one another. For the purpose of establishing such a scale, the Bureau has been making inquiries of the manufacturers using wire sieves in grading or testing their products to determine the sizes of sieves most used, with a view to preparing specifications for a scale of screens which may be suitable for all industries making use of sieves. A final decision has not as yet been reached in this matter.

Volumetric Glassware.

The glassware tested by the Bureau comprises flasks, cylindrical graduates, transfer pipettes, measuring pipettes, burettes, and Babcock test bottles. A great deal of this testing is done for various branches of the Government service. There has been a very considerable falling off in the number of pieces of volumetric glassware submitted for test during the year, only 1,632 pieces being received; but the lessening of work on this account has been more than counterbalanced by the 2,306 hydrometers submitted, against 1,213 last year, and 309 density determinations made, against 109 the previous year.

Density determinations on samples of sea water were made during the year in connection with the ice patrol being carried on by the Government in its safety work on the North Atlantic Ocean. It is expected that further samples will be collected and their densities measured at various temperatures, in order to determine the relations existing between density, temperature, and salinity of sea water.

Density Tables for Petroleum Oils.

Petroleum-oil tables were prepared during the year and will be published in the form of a circular. The density and expansion of American petroleum oils obtained from the oil fields of California, Indiana, Louisiana, Ohio, Oklahoma, Pennsylvania, and Texas were determined, and form the basis of the tables. These tables, comprising about 100 pages, will be found of great practical value in the oil trade in various ways, such as in calculating the number of gallons of oil in large shipments when the quantity is determined by weight and in ascertaining the quantity of oil in storage tanks.

Barometry.

Apparatus has been constructed and used for calibrating aneroid barometers at $-35°$ C., the cooling being done by carbon dioxide and the temperature controlled by lamps and fan in a vacuum chamber.

Investigations of aneroid barometers previously conducted by the Bureau have been confined to the inherent errors of the instruments. The consideration of secular or of transient errors, being less urgent, was not taken up for careful study until the present year. Regarding these latter errors, certain facts have been established by suitable experiments, (*a*) concerning the nature of the changes occurring in use and transportation, and the causes giving rise to them; (*b*) concerning the temperature lag of the air, inside the aneroid, or the time needed for the temperature difference to drop to about one-third of its initial value, which was found to vary according to the style of case and degree of circulation of air and from which conclusions were drawn as to the time necessary in test. It further appears that transient thermal errors are wholly due to this temperature lag, and not to local heating.

It has been found by experiment that aneroid barometers may be successfully compensated against temperature effects at constant pressure, but still go seriously in error when temperature and pressure are both changed. Apparatus has been constructed for changing the temperature and pressure at the same time. The specification of this error has been reduced to a quantitative basis, and has been called the temperature coefficient of scale value to distinguish it from the previously recognized temperature coefficient of reading.

During the year 16 aneroid and 7 mercurial barometers were tested.

Testing of Watches.

The testing of watches for the public, a line of work which was inaugurated last year, has been continued this year. Three trials, involving the test of 30 watches, have been held during the year, each test lasting 54 days.

Watches are divided by the Bureau into two classes according to the character of the tests, namely, Class A, for watches adjusted to five positions, and Class B, for watches adjusted to three positions. A certificate of performance is issued to all watches passing the test.

The regulations under which the watch tests are conducted, including criteria and tolerances by which the performance of each watch is judged, were issued in the form of a circular during the past year. This circular includes suggestions on the care and handling of watches, a list of the stations sending out time signals, and a list of the boundary points between the various standard time sections.

In addition to the regular test of high-grade watches, the Bureau has commenced an investigation of stop watches, chronograph watches, and timers, for registering short intervals of time, principally for the purpose of determining the suitability of various kinds to the needs of the different branches of the Federal Government. The Bureau is also investigating the relative reliability of cheaper grade of watches for the purpose of obtaining some definite information as to rates of watches having fifteen jewels or less, the degree of isochronism they have, and what is the usual accuracy of their adjustment for isochronism. From these data a definite idea of the relative merits of watches of different grades will be obtained, a point concerning which very little information is available.

Precision and Empirical Equations.

There has long been felt the need of a simple and definite rule for estimating the precision of the constants of linear empirical equations, since nearly all of the work done by the Bureau in determining the properties of materials and the corrections of measuring instruments falls under this head. The rules afforded by the classical texts on least squares have never come into practical use, because they are enormously complicated and not primarily concerned with the facts the laboratory wants to ascertain. This need has been filled by certain formulas which have been devised and which have proved very useful in the regular work of the Bureau.

Inspecting and Testing Scales.

During the first three months of the last fiscal year 5,000 parcel-post scales for the Post Office Department were inspected at the plant of the Triner Scale & Manufacturing Co., Chicago. On this contract valuable work was done by the Bureau in improving the general design of the scale and the details of its construction and manufacture. These scales were equipped with approximately 175,000 single counterpoise weights, each of which had to be separately inspected and tested for accuracy before acceptance. It was necessary to devise special methods of testing in order to make it possible to test so large a number of weights individually without an inordinate expenditure of time and effort.

During the year a large number of tests were made on new scales and scales in service, on the request of the Post Office and other Federal departments. Especially important was the work of scale testing done for the Navy Department at the various navy yards on the eastern coast, detailed recommendations being furnished that department in relation to the methods to be used in the installation, operation, maintenance, and test of the numerous scales under its jurisdiction. A total of 78 scales other than railroad track scales were tested for this department in connection with the work of the test car.

A number of scales were also tested for the War Department at Fort Hunt, Va., and Fort Washington, Md.

A sample of an automatic scale and one of a hanging spring-dial scale, submitted to the Post Office Department for the parcel-post service by a Chicago contractor, were given a thorough inspection and test with regard to points of design, and numerous recommendations were made relative to making the scales suitable for use in the postal service.

The preliminary study made of the damping of scales resulted in the discovery of considerable useful data relative to the amount of friction which will be met in commercial scales and disclosed valuable information relative to the comparative merits of two different lever systems in the matter of variability and inaccuracy due to friction.

A careful test and inspection were made, and a full report submitted, on a number of samples of stabilized equal arm trip scales submitted by a New York City manufacturer, who submitted these scales to the Bureau with a view to obtaining an opinion on their

design and construction and receiving suggestions as to the methods which should be employed to improve them.

New drawings were prepared for one of the approved types of 50-pound cast-iron test weights, and of the various forms of approved sealing devices for closing the adjusting cavities of Class C weights.

A paper was prepared on the subject of automatic scales, and read before the Tenth Annual Conference on Weights and Measures. For the purposes of this paper, information was compiled in large amount in relation to the various types of automatic scales on the market, and drawings and literature of every sort were procured and placed on file for reference on this important subject.

In connection with the same paper, a study was made of the cam and pendulum construction used in the more usual types of automatic scales, and useful analytical and graphical methods were devised for the design of the cams used in these scales. This is work of very great importance to the manufacturer and should be developed more fully, as the amount of exact information available to the designer of this apparatus is very meager.

The Bureau acquired during the year a large platform scale of 10,000 pounds capacity, mainly for the purpose of checking its own standards of this denomination, which form a part of the railroad track scale testing equipment of the Bureau. This has temporarily been installed in the engineering shop in order that the crane forming a part of the equipment in that shop might be used to handle the large masses involved. It is doubtful, however, whether the floor of the shop is sufficiently strong to carry the additional weight involved in the test of such large masses, and it is urgently recommended that a special laboratory with a suitable crane and foundation be provided for the test of heavy weights, for which there is an increasing demand. Such a laboratory would also afford facilities now lacking and badly needed for erecting and testing large scales and provide much-needed room for the scale-inspection work of the Bureau.

Operation of Test-Car Equipment.

The equipment for testing railroad track scales, purchased in 1913, has been in continuous service during the year, with the exception of a period of about one month, when it was withdrawn in order to make necessary repairs. Subsequent to the test and standardization of a master scale for the State of Minnesota, in July, 1914, 338 railroad-track scales in the States of Minnesota, Wisconsin, Indiana, Iowa, Missouri, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, and the District of Columbia; and 78 scales other than railroad-track scales, in the navy yards at Norfolk, Va., Charleston, S. C., Key West, Fla., and Pensacola, Fla., were tested. These scales were located in 86 different cities or towns, and of the track scales 241 were owned by railroads, 89 by manufacturing concerns, and 8 by the Federal Government.

Condition of Track Scales.

Of the 338 track scales tested, 107, or about 32 per cent, passed and 231, or 68 per cent, failed to pass the tolerance adopted by this

Bureau, which allows a maximum possible error of 200 pounds in weighing a car of 100,000 pounds. The magnitude of the possible errors of weighing a 100,000-pound car were found to vary in commercial scales from 30 pounds to 21,600 pounds.

Reports giving the condition of the scales tested have been rendered to the States which have organized departments of weights and measures. They have also been rendered to the owners of scales when such reports were requested, in which were given the condition of the scale and advice relative to the proper maintenance and repair of the scale. These individual reports, beginning June 1, 1915, were sent to the owners whether they were requested or not. The acknowledgments of these reports show that the work is appreciated and that frequently repairs and new installations follow as a result.

Progress has been made in developing improved methods of testing and adjusting track scales, and considerable work has been done relative to the establishment of a standard method of determining their capacity. Several scales were examined and their capacity determined for State departments, but it was found necessary to limit this work to a very small amount, owing to the smallness of the force.

Specifications were prepared for the use of the National Zoological Park in the purchase of auto truck scales. Some progress has been made in the preparation of railroad-track scale specifications which will be of value to scale manufacturers, purchasers, and users.

An effort has been made to serve as many States and as large a territory as possible with the equipment available, but with 21 States visited to date since October, 1913, it is apparent that more than the present car and the one soon available will be needed in order to carry out even a small part of the work. An additional office force will also be required to handle the results of the track-scale tests and perform the work in the numerous other fields, such as grain weighing, at present awaiting development.

Linear Expansion of Materials.

During the year the range of temperature available for measurements of thermal expansion, electrical resistance, and magnetic permeability in the oil bath regularly used to over 300° C. was extended downward to a temperature of —40° C.

Improvements have been made in the electric furnace used for heating uniformly specimens under test for thermal expansion. Specimens need no longer be limited to the single length of 30 cm. and a diameter of from 5 to 10 mm.; the furnace is now capable of receiving specimens having any multiple of 5 cm. up to 30 cm. in length, and almost any cross section, not necessarily uniform, up to 2 or 3 cm.

The simultaneous measurements of thermal expansion and electrical resistivity, which were commenced a little over a year ago, are progressing favorably and data are gradually accumulating.

An investigation has been started to obtain new data on the thermal expansivity of fused silica (quartz glass) throughout a wide temperature interval, and to compare the expansivities of various specimens prepared under different conditions. There has been acquired by the Bureau a set of 20 specimens, especially prepared for

this investigation, and representing in duplicate the five types of products, both annealed and unannealed, made by the donor of the specimens. Since fused silica has already become a sort of international standard for thermal expansion, it is important to know the nature and extent of variations in the expansivity of specimens from various sources and subjected to various treatments. It has a wide range of commercial uses, on account of its small expansivity and its resistance to the action of many chemicals. The investigation now in progress is likely to explain why certain types of the product give better results than others.

A study of the expansivity of nickel steel has been commenced for the purpose of assisting American manufacturers in developing methods for producing nickel steels of specified thermal expansivity combined with stability of dimensions and other desirable properties. At the present time practically all nickel steel for scientific purposes is imported from Europe.

Experiments on the expansion of structural steel and the elastic properties and strength of materials at high temperatures have been undertaken in connection with the investigation of fire-resisting materials being conducted by the Bureau. Studies will be carried out on the expansion of specimens selected from different parts of typical steel shapes, in order to determine the change in length on first heating steel beams or columns to high temperatures, and to ascertain whether this expansion is uniform or not throughout the section. These investigations are to obtain data much needed by engineers for designing structures that may be subjected to temperatures above the ordinary atmospheric range.

Annual Conference on Weights and Measures.

The Tenth Annual Conference on Weights and Measures was held May 25–28, 1915, at which there were present 28 delegates representing 18 States, the District of Columbia, and the Philippine Islands; 69 city and county weights and measures officials; and about 80 visitors, representing railroads, manufacturers of weighing and measuring apparatus, trade bodies, etc.

The purpose of the conference is to bring together State and local weights and measures officials to discuss administrative and technical problems which arise in the work. It also serves to point out the great financial saving to the public in having State supervision and local inspection of all weights and measures in commercial use. When it is considered that within the decade that these conferences have been taking place about two-thirds of the States have undertaken this work and vast improvement is reported from practically all sections of the country, it may be presumed that the conference is having marked success in this important economic work.

Tolerances and Specifications.

One of the most important accomplishments of the Annual Conference on Weights and Measures, from an administrative point of view, is the adoption of tolerances and specifications for weights and measures and weighing and measuring devices. The necessity for uniform tolerances and specifications is a pressing need, on account of the vast interstate commerce carried on in the United States, and

it is believed that those adopted at the last conference will meet this need, which is felt by all weights and measures officials. Heretofore there have been no regulations of this character recognized by the various States.

So-Called Net-Weight Amendment to the Pure-Food Law.

In the amendment of March 3, 1913, to the National Food and Drugs Act of June 30, 1906, provision is made with regard to food in package form for the establishment by rules and regulations of reasonable variations and tolerances, and also exemptions as to small packages. This Bureau is cooperating with the Bureau of Chemistry of the Department of Agriculture in the collection and analysis of data on the weight and methods of packing food put in package form, with a view to establishing tolerances and variations provided for in the law. This investigation has been going on for a number of months and satisfactory progress is being made.

Standard-Barrel Act.

An act establishing a standard barrel was passed by Congress last winter and approved March 4, 1915. This act, known as the "standard-barrel law," fixes a standard barrel for fruits, vegetables, and other dry commodities, and certain subdivisions thereof, and a standard barrel for cranberries. This act refers both to interstate and intrastate transactions and is the first mandatory standard for general commercial use ever established by Congress under the power given to that body by the Constitution "to fix the standard of weights and measures." It is expected that this will be of great help to manufacturers, shippers, commission men, and consumers, since for the first time the term "barrel" will have a definite and certain meaning in the United States. Reasonable variations from the standard are permitted and the Bureau of Standards is empowered to establish tolerances and rules and regulations for the enforcement of the act.

Efforts to obtain uniform weights and measures laws among the States have continued to receive the earnest support of the Bureau, and have met with gratifying success during the past year. Among the States to which assistance was rendered by this Bureau and in which satisfactory legislation was passed may be mentioned Oklahoma, Oregon, West Virginia, Utah, Minnesota, and California.

Information Furnished on Subjects Pertaining to Measures of Length, Mass, Capacity, and Time.

Information concerning screw threads has been furnished in answer to numerous inquiries with regard to the correct figures for, and the use of, various screw-thread systems, wire, and sheet-metal gages. Among the tests made was one on the determination of the variation in pitch of a screw and the standardization of a bar, both to be used in a comparator for the verification of the accuracy of the standard gages, limit gages, etc., made by a well-known manufacturer of machine and mechanical specialties.

The Bureau has kept in touch with the work of the committee on tolerances in screw-thread fits of the American Society of Mechanical Engineers, and was represented at several meetings of the committee.

There has been an increasing demand for information as to instruments and methods for measuring the humidity of the atmosphere. A large number of letters have been written and a number of psychrometer charts have been prepared and sent out.

As an example of the value of the Bureau's work on the density and thermal expansion of petroleum oils, it may be stated that the rate of expansion of a sample of fuel oil was measured for a railroad company in order to determine whether the temperature correction factor for specific gravity should be 0.0004 or 0.0005 per degree Fahrenheit. It was stated by the railroad company that this difference in expansion meant a gain or a loss to them of between 2,000 and 3,000 barrels of oil per month on a single contract.

Information, specifications, and blueprints for the construction of bench standards for the comparison of steel tapes have been furnished two organizations planning to construct such standards.

The Bureau receives a large number of letters from weights and measures officials throughout the country asking for information and advice concerning their work. It is the aim of the Bureau to assist these officials in every way possible, and to cooperate with them in their work.

Publications on Weights and Measures.

There have been published during the year the report of the Ninth Annual Conference on Weights and Measures; Circular No. 51, Measurement of Time and Test of Timepieces; and Circular No. 47, Units of Weight and Measure.

A paper covering the barometry investigations of the Bureau has been practically completed for publication in the Bulletin of the Bureau. It presents concisely and without experimental details the final and practical results of the various barometry investigations conducted by the Bureau.

2. THERMOMETRY, PYROMETRY, AND HEAT MEASUREMENTS.

Platinum Resistance Thermometers.

The construction of 11 platinum resistance thermometers has been completed. These thermometers, which involved the most painstaking workmanship, are designed for measuring temperatures with the highest attainable accuracy from —200° C. to about 600° C., and when standardized will serve as the instruments for reproducing the standard scale of temperature of the Bureau. The instruments designed for low temperatures are provided with means for drying the air within the thermometers to prevent the condensation of moisture on the coil and leads. The instruments designed for measuring small temperature changes of a few degrees with an accuracy of a few ten-thousandths of a degree, besides being provided with drying heads, are inclosed in closely fitting platinum cases from which the coil is insulated by the thinnest sheet of mica, so that the thermometer coil will follow rapidly varying temperatures with the minimum of lag. This type of thermometer, which was developed by the Bureau and which has been described in Scientific Paper No. 200, is finding extensive use in engineering and research laboratories. The high-temperature thermometers are mounted in externally glazed porcelain tubes. All of the thermometers are con-

structed so that variable lead resistance can be eliminated, and stray electromotive forces are reduced to a minimum. On account of its high electrical conductivity, resistance to oxidizing influences, and small thermoelectromotive force against platinum and copper, the thermometers are provided with gold lead-wires, with the exception of the calorimetric type, which have the usual flat copper leads to the platinum coil.

A Wheatstone Bridge for Resistance Thermometry.

The highest accuracy attainable in the measurement of small temperature intervals met with in calorimetry with the most carefully standardized thermometers of the mercurial type is of the order of 0°.002 or 0°.003 C. When higher accuracy is required, use must be made of electrical thermometers of the resistance or thermoelectric types, used in connection with a suitable resistance bridge or potentiometer. The present bridge was especially designed for the requirements of the Bureau in calorimetric work of the highest accuracy. Special features are mercury contact links, the use of shunt dials for the 0.0001, 0.001, and 0.01 ohm decades, a new form of hermetically sealed coil, and complete oil immersion of contacts as well as coils in order to reduce disturbing thermoelectromotive forces. Measurements by the Thomson double-bridge method are also provided for. A complete description of this bridge has been published in Scientific Paper No. 241.

As a result of the experience gained with the use of this apparatus, a simplified type of bridge adapted to resistance thermometry has been designed and constructed and has been in use for a year or more. This will be described in a future number of the Bulletin of the Bureau.

A Multiple Junction Thermoelectric Thermometer.

A multiple junction thermocouple, made by the Geophysical Laboratory and kindly loaned to the Bureau, was standardized by comparison with a platinum resistance thermometer to an accuracy of 0°.001 or 0°.002 in the range 0° to 50° C. This multiple thermocouple has been used by the above laboratory to standardize a number of their couples and it thus serves to define the temperature scale for the precision work of that laboratory in the range 0° to 50° C.

The Emergent Stem Correction for Thermometers in Creosote Oil Distillation Flasks.

Thermometers used in distillation flasks are subject to error if a portion of the thermometer stem, containing the mercury column, is emergent from the flask and is at a temperature different from that of the bulb.

This emergent stem correction error is discussed with particular reference to creosote oil distillation. Emergent stem corrections were determined, applicable to a particular type of thermometer when used in four types of distillation flasks.

The average correction found for the ordinary side-neck distillation flask at 200° C. was 4°.5; at 250°, 6°.0; at 300°, 10°.5; and at 350°, 15°.5, with differences of as much as a degree between the same

readings on different runs, making it evident that the average corrections could not be relied upon to better than a degree. For the same temperature, using the same thermometer in different flasks, the greatest difference in the stem corrections found was 2° C.

Reasons for variations in emergent stem corrections for different runs on the same flask are discussed. The greatest errors are caused by the use of unsuitable thermometers and variations in the rate of rise of temperature. The most suitable thermometer for distillation flasks seems to be a continuous-scale graduated stem type of mercurial thermometer having a length of about 40 cm.

The effect of radiation and condensed vapor on the temperature measurement is discussed.

The magnitude of the disagreement in distillation results when in one case allowance is made for stem correction and in another case it is not, is shown by example.

A method was suggested by which the total correction (including scale correction and emergent stem correction) to a thermometer used in distillation flasks can be determined at two points by reading the thermometer first in the vapor of boiling naphthalene (temperature 218° C.) and then in the vapor of boiling anthracene (temperature 340° C.). Interpolations for the corrections between these two points can then be made. This method was investigated and found to be reliable to 1° or 2°. This investigation has been published under the above title in Technologic Paper No. 49.

Low-Temperature Thermometer Comparator.

A low-temperature comparator was designed and built. It consists of a large cylindrical Dewar flask containing a suitable liquid (gasoline or pentane) and is provided with a motor-driven stirrer. Cooling to —50° C. is effected by expanding (through a sensitive valve and an immersed coil) carbon dioxide obtained from the CO_2 compression system maintained at the Bureau. Below —50° C. liquid air supplied through a siphon in the required quantity is used and temperatures down to —150° may be obtained. An electric heating coil in the bath is used to aid in temperature regulation. An investigation of the temperature distribution in the bath has shown that at —50° the temperature over a length of about 25 cm. is uniform to 0°.01 or 0°.2 C.

Specifications for Laboratory Standard Thermometers.

Some time has been given to the preparation of specifications for high-grade laboratory thermometers of a type suitable for working standards in the laboratories of the Bureau and in other scientific and technical laboratories. After the thermometers made up in accordance with these specifications have been thoroughly tried out and the specifications have been finally revised in the light of the experience resulting therefrom, it is planned to publish a circular on specifications for laboratory standard thermometers. Such a circular would answer numerous inquiries addressed to the Bureau on this subject and would be of great service to many scientific and technical laboratories in furnishing information as to the equipment of the laboratory with reliable working standards.

Recording Deep-Sea Thermometer.

At the request of one of the Government bureaus, designs were prepared for a deep-sea thermometer which would give a continuous record of deep-sea temperatures with an accuracy much greater than is attainable with the ordinary reversing type of mercurial thermometer, an accuracy of 0°.01 being desired. The principle adopted is similar to that of the mercurial thermostat, except that the platinum contact point is movable. This contact point, mounted on the lower end of a steel rod (0.5 mm.), is driven downward through the bore of the capillary by clockwork mechanism until the platinum point comes into contact with the mercury meniscus, when an electric circuit is closed, the rod lifted upward a short distance, after which it again proceeds downward as before. The upper end of the rod carries a point which marks a continuous line on a roll of paraffined paper, a scale being simultaneously recorded by similar means. The whole mechanism is inclosed in a steel cylinder (40 cm. high by 12 cm. diameter) capable of resisting deep-sea pressures.

An opportunity has not yet been found for constructing and trying out this design.

Other Thermometric Investigations.

Owing to the very great demands on the thermometric section for testing, it has been possible to give but little time to several investigations that have an important bearing on the work of this section.

There has been a considerable demand both from other laboratories of the Bureau and from outside laboratories for thermocouples standardized at very low temperatures (—200° C.). A stock of special wires for this purpose was purchased some time ago and it would be of great advantage to the Bureau to standardize these wires so that they could be issued for use for low-temperature measurements. It is hoped that the necessary assistance can be given to this section so that the important work of establishing the low-temperature scale can be taken up and completed in the near future.

Some progress is reported on the following investigations:

The standardization of the specially designed and constructed platinum resistance thermometers described in the earlier sections of this report.

The determination of the "ice-point depressions" of different thermometric glasses after heating and of the rate of recovery of the same.

The standardization of a complete set of mercurial thermometers for use as working standards in the interval —40° to 500° C. The completion of this investigation is essential to the work of testing.

Characteristics of Radiation Pyrometers.

Radiation pyrometers are instruments in which the measurement of the temperature of a body is based on the measurement of the intensity of the radiation (both light and heat) emitted by that body. The object of these present investigations has been twofold—(1) to assist the pyrometer manufacturer in producing a more reliable and satisfactory instrument and (2) to call attention to the possibilities of the instrument, and the precautions which must be understood by technical and scientific men who employ this method of temperature

measurement. Full details of this investigation have been published in Scientific Paper No. 250. The paper treats in detail the following subjects:

1. General principles of radiation pyrometry, fundamental equations, and mechanical requirements which must be considered in the construction of the instrument.

2. Types of radiation pyrometers. The construction of the various pyrometers available is discussed, and the principles upon which many of the working parts operate are considered.

3. Methods of calibration. Two methods are given, one a primary method in which the calibration is obtained by sighting the pyrometer into an opening in a uniformly heated inclosure, known as a "black body," the temperature of which can be measured by thermocouples. The other method is a secondary method which may be used to calibrate other pyrometers by comparison with a standard pyrometer calibrated by the first method.

4. Method of use. Under this heading are considered methods of obtaining the reading of the pyrometer, extrapolation of the temperature scale to higher temperatures than those at which a calibration can be made, methods of automatically recording which permit a continuous automatically printed record of the temperature of a furnace during a prolonged run, as well as a check upon the operators of the furnace. These records are very valuable in the technical industries. Radiation pyrometers in general require a rather large source upon which the pyrometer is sighted. Methods are given for obtaining the correct temperature when the source is of insufficient size to meet this requirement.

5. Discussion of errors. The elimination of the errors in measurements with radiation pyrometers is of great importance. These errors are considered in detail for every type of instrument. If the precautions given are strictly followed, the temperature measurements can be relied upon. If these precautions are not followed, errors may be involved of such magnitude that in general the readings of the instrument will be of no value whatever.

6. Applications. The use of the radiation pyrometer for the study of the radiating properties of glowing materials is considered, and data are given for correcting the readings of radiation pyrometers, sighted upon several metals and oxides in the open, to true temperatures.

Radiating Properties of Metals and Oxides.

An important factor in recent metallurgical progress in the development of special alloys is the better control of temperatures that is now possible.

In many of these processes the temperature must be measured by optical or radiation pyrometers. These pyrometers read incorrectly when sighted upon glowing metals in the open. It has been the purpose of this investigation to determine the corrections necessary to apply to the pyrometer readings to obtain the correct temperature of the material sighted upon. The investigation of nickel oxide was reported last year. The paper has since been published as Scientific Paper No. 224. Partly from the purely scientific interest, the radiation of platinum has been studied and a theory has been

developed connecting the total radiation with the resistance and temperature of a metal. This work was published in Scientific Paper No. 243. The fourth number in this series, Scientific Paper No. 249, is an investigation of the radiometric properties of iron oxide. Corrections are given which permit the measurement of the true temperature of a steel rail; for example, as it passes through the rolls. The temperature gradient through the layer of oxide formed upon glowing iron in the open air was also measured. The outside oxide layer on a glowing iron rail may be 100° cooler than the iron immediately under the oxide.

In the coming year these investigations will be extended to other metals and oxides.

Other Investigations Relating to Pyrometry.

Some time has been given to the preparation of papers on "The Center of Gravity and the Effective Wave Length of Transmission of Pyrometer Color Screens" and on "A New Relation Derived from Planck's Law," which will be completed and submitted for publication early in the next fiscal year.

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.

Standard Heat Samples.

In the last annual report was described the determination of the heats of combustion of specially purified samples of cane sugar, benzoic acid, and naphthalene. This work has since been published in Scientific Paper No. 230. Samples of these substances 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 heat values of fuels, foods, etc. Two hundred and fifty-three 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; and chemical manufacturing plants; as well as to university, technical, municipal, State, and National testing laboratories and bureaus.

As time permitted, determinations have been made of the heats of combustion of other substances, such as hippuric acid, anthracene, camphor, phthalic acid, pthalic anhydride, and salicylic acid. The samples on which these determinations were made were prepared several years ago. The determinations should be repeated on more recently purified samples before the results are ready for publication.

Another calorimeter jacket, very similar to that used in the investigation above referred to, has been constructed by the instrument shops of the Bureau, and detailed working drawings have been furnished to a manufacturer who contemplates putting it on the market so that it will be available to laboratories requiring the highest accuracy in calorimetric measurements.

A new edition has been issued of Circular No. 11, entitled "The Standardization of Bomb Calorimeters." This circular contains more complete information on the use of the standard heat samples for the standardization of bomb calorimeters than was contained in the previous edition. The most important feature of the circular, however, is the change in the standard heat unit of the Bureau, effective July 1, 1915, to which change attention is directed. After careful consideration the Bureau has decided to adopt as the fundamental unit of heat the calorie, expressed in terms of the capacity for heat of water at 20° C., instead of at 15° C., as heretofore.

Gas Calorimetry.

The publication of Technologic Paper No. 36, on "Industrial Gas Calorimetry," and of Circular No. 48, on "Standard Methods of Gas Testing," both of which were reviewed in last year's report, has resulted in greatly increasing the demands on the Bureau for the testing of gas calorimeters, the work in this section being several months in arrears.

A member of this division together with a member of the chemical division were called on as referees to investigate the differences in the results of heating value tests found in a large eastern city by the engineers of the State public-service commission and by the engineers of the public utility supplying the gas.

An investigation that has been carried forward from year to year is one relating to the determination of the heating value of the more important elementary gases that enter into the composition of natural and manufactured gases. Some progress can be reported this year by the chemical division in the preparation of very pure hydrogen for this work and by this division in a number of determinations of the heat of combustion of samples of this hydrogen. It is to be hoped that the necessary assistance can be given to this section to take care of the increasing demands for testing, so that greater progress will be possible on this important investigation.

An Aneroid Calorimeter.

For the measurement of specific heats and latent heats of substances under pressure (for example, anhydrous ammonia, carbon dioxide, etc.) and for other purposes outside of the range of application of the familiar form of liquid calorimeter, there was developed a calorimeter which utilizes for equalization of temperature the thermal conductivity of a solid copper shell in connection with a built-in heating coil and a built-in platinum resistance thermometer. Details of the design, construction, and operation are described in Scientific Paper No. 247. Results of the standardization of the instrument are given, and also, as the results of a test of its performance, a few experimental determinations of the specific heat of water in the interval from 0° C. to +40° C. The precision attained was

such as to indicate an entirely satisfactory performance of the calorimeter. The results of these determinations are in fair agreement with the mean of a number of the more reliable measurements in recent years, but must not be considered as an authoritative measurement by the Bureau of this very important quantity.

Specific Heat and Heat of Fusion of Ice.

As a part of the program outlined later under the title "Refrigeration constants" there were completed a series of experimental determinations of the specific heat of ice in the temperature range from —40° to 0° C. and of the heat of fusion of ice. The measurements were made by means of the calorimeter of aneroid type described above.

The specific heat of four samples of ice, all of high but of different degrees of purity, was determined. By analysis of the results the conclusion drawn is that (s) the specific heat of pure ice, may be represented between —40° and —2° by the equation $s=0.505_7+0.00186_3\theta$, the unit being the 20° calorie, and θ being the Centigrade temperature. Between —2° and —0°.05 the specific heat does not exceed the value given by this equation by more than $0.004/\theta^2$. The specific heat of impure ice, within the same temperature interval, was found to be greater than that of pure ice by an amount $80\ 1/\theta^2$, where 1 is the (centigrade) freezing temperature of the ice. The value found for the latent heat of fusion of ice is 79.76 20° calories per gram, which is within 1 part in 4,000 of the value determined last year by an entirely different method. The results are communicated in Scientific Paper No. 248.

Heat Capacity of Water and the Mechanical Equivalent of Heat.

No progress has been possible on this investigation during the past year.

This investigation is of fundamental importance in fixing the primary unit of heat. In the half dozen or more extended pieces of work that have been published on this subject, which may be said to be more or less generally accepted, there appear startling discrepancies, and it is evident that this fundamental measurement has not been made with anything like the degree of accuracy which modern calorimetric practice demands. In the course of the calorimetric researches that have been under way in the laboratories of the Bureau during the past several years, a great deal of valuable data have been obtained on the capacity for heat of water. The work has suggested improvements in apparatus and in methods of experimentation which will be tried out as soon as opportunity permits. In view of the importance of the work and of the discrepancies in existing data, it is deemed best to withhold publication until the work has been carried out with the highest accuracy that can be obtained by the best modern methods.

Control of Atmospheric Humidity in Laboratory Rooms.

In many technical and scientific laboratories the effects of atmospheric humidity are such that it becomes of importance to maintain constant conditions not alone as to temperature but as to

humidity as well. Examples of such laboratories are certain customs and textile laboratories and electrical laboratories. This division has been cooperating with some of the other divisions in a study of feasible methods of controlling atmospheric humidities in laboratory rooms.

Constant Temperature Room.

One of the laboratory rooms was rebuilt during the year as a special constant temperature room for the thermal conductivity measurements. The walls were well insulated and a special cooling and heating system with automatic control installed, so as to maintain any temperature from that of freezing water to as hot as an observer working in the room can stand. The room was designed especially for service tests of pipe coverings, which series of tests can be started as soon as observers may be available to assign to it.

Thermal Conductivities of Insulation and Building Materials.

This work has been undertaken at the request of the railway companies in connection with insulation requirements of steel passenger-car construction, and the Railway-Mail Division of the Post Office Department, in connection with insulation specifications for steel postal cars; the manufacturers of building insulation materials, steam and brine pipe coverings, etc.; the furnace construction industry; and the furniture construction and refrigeration industries, in connection with the construction of cold rooms and refrigerators. Thermal conductivity data are also of importance in connection with building construction in its bearing on the heating of buildings, the resistance of walls, floors, etc., to the flow of heat and transmission of fires, the effectiveness of fireproof coverings of columns, girders, etc.

Notwithstanding the fact that thousands of thermal conductivity measurements have been made in many different laboratories, the results are extremely unsatisfactory, showing wide discrepancies. The need of standardization is obvious, but the problem presents unusual difficulties and the progress of the investigation is necessarily slow.

A piece of trial apparatus, taking samples in the form of slabs about 8 inches square, has been in satisfactory service for some months, and a similar apparatus for much larger samples has been constructed and used to some extent. Preliminary reports of the work have been submitted for criticism and consultation to the manufacturers who furnished samples. Especial attention is being given to the investigation of the factors which determine the insulating properties of an air space, such as thickness of air layer, distance between baffle plates to break convection streams, etc. A proper understanding of these factors will have an important bearing on the cellular wall construction of cold rooms, refrigerator cars, and car insulation in general.

Some time has been given to the design of an apparatus adapted to the determination of the thermal conductivities of materials up to temperatures corresponding to red heat, as well as at ordinary temperatures.

Temperature Conductivity of Cotton Bales.

For the purpose of determining the feasibility of destroying by heat a particular boll weevil found to be present in bales of imported Egyptian cotton, the Bureau of Entomology of the Department of Agriculture requested this Bureau to determine the time required to bring all points in the interior of a bale of cotton to a certain minimum temperature, when the exterior was maintained at a higher known temperature.

To this end copper-constantan thermocouples were placed, with considerable difficulty and labor, at various points in the interior of the bale, the bale placed in a specially thermostated constant temperature room maintained at approximately 150° F., and readings taken hourly, both day and night, for about one week, on the thermocouples in the interior of the bale, until they all reached a temperature somewhat in excess of 120° F., which was the temperature supposed to be necessary to destroy the boll weevil. A complete report of the results of this test was submitted to the above-mentioned bureau.

Tests of Household Refrigerators.

A comprehensive test of commercial refrigerators was carried out for the War Department as a basis for the award of a contract. These tests related to ice consumption, temperature distribution, and air circulation within the refrigerators. As a result of the data obtained in these tests, the Bureau is endeavoring to cooperate with manufacturers in the direction of improvement of this product. Parts of this test of refrigerators are necessarily confidential, but the parts that can be made public are summarized in a popular manner in Circular No. 55, "Measurements of the Household."

It is hoped that an opportunity will be found to make more extensive tests along these lines, especially on the cheaper grades of refrigerators in common use in the household. Deficient insulation may result in unnecessary expenses and waste, and very often it would be possible for the manufacturer to very materially increase the efficiency of his refrigerator without any very significant increase in cost. Inefficiency is probably as often due to lack of knowledge of the important features of the design, of physical properties of materials used, etc., as it is to an attempt to cheapen manufacturing costs.

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 several occasions liquid air has been furnished for lectures before teachers' organizations. The carbon dioxide compressor has been operated almost continuously throughout the year to operate low-temperature baths required by the investigation of refrigeration constants and by the thermometer laboratories.

Three new liquefiers have been constructed and tried out. One of these has a capacity, when used with brine precooling, of about 6 liters of liquid air per hour.

A new electrolytic oxygen and hydrogen gas generator has been installed for furnishing these gases to the chemical laboratories.

Industrial Viscosimetry.

The most important laboratory test of the lubricating value of an oil for the purpose in view is the viscosity test. The instruments most widely used by the oil industries in the specifications of the viscosities of lubricating oils, in domestic and foreign commerce, are the Saybolt-Universal, the Engler, and the Redwood viscosimeters. At the request of the American Society for Testing Materials and of many industrial oil chemists, the Bureau undertook an intercomparison of these instruments and recently submitted a report of this work to the above-mentioned society. This report contains suitable conversion tables so that results found with any one type of these instruments can at once be converted to the scale of either of the other two types.

The Bureau is constantly receiving requests from technical men for information on the measurement of the viscosity of lubricating oils. Nearly fifty long letters and reports were prepared during the year in reply to such requests. More assistance is needed for this work, which at present is carried as a side line by one whose time is otherwise more than fully occupied. Important work that has been deferred from year to year is the preparation of a circular on industrial viscosimetry which would serve to answer numerous inquiries such as are referred to above. The Bureau is constantly in receipt of requests for standard viscosity samples, which would enable oil chemists to standardize and check from time to time their viscosimeters, in the same way that they now can check their heating value tests by means of the standard heat samples furnished by the Bureau. This work can be placed on a most satisfactory basis as soon as an assistant can be assigned to it.

Standardization of Flash-Point Testers.

One of the important tests of an oil to determine its safety in use and its suitability for particular applications as well as for compliance with specifications is the determination of its flash point; that is, the temperature at which it gives off volatile vapors that will ignite explosively if brought into contact with a flame or object at high temperature. This flash point is dependent not alone upon the chemical constitution of the oil, but is very materially influenced by many other factors, such as whether the cup is open or closed, the form and dimensions of the apparatus, the point of application of the flame, the size of the latter and time of its application, the protection against air draughts, the height of the oil in the cup, the degree of stirring of the oil, the method of taking the temperature of the oil, the rate of heating the oil as the flash point is approached, the barometric pressure, and many details of manipulation. Hence, it is of importance to investigate the effect of these various factors to enable the test to be standardized.

The Bureau has undertaken the standardization of the flash-point testers of the Abel-Pensky and of the Pensky-Martens types as modified by the Bureau of Mines. Four of these instruments were submitted for test in March, 1915, and a considerable amount of experimental work was done with them. As a result of this work certain modifications were proposed and are now under consideration by the Bureau of Mines. Arrangements have also been made to

cooperate with that bureau on the preparation of the necessary standardization specifications and of the operating directions.

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 and the latent 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 investigation involved the original design and the construction in the instrument shops of the Bureau of a large number of accurate and complicated pieces of apparatus. These have been remodeled as the experience gained in their use dictated, and the actual measurements made with them have progressed as follows:

The measurements upon ice have been entirely completed and published (*a*) in Scientific Paper No. 209, reviewed in last year's annual report, and (*b*) in Scientific Paper No. 248, reviewed in an earlier paragraph of this report. The results of this latter were communicated to the American Society of Refrigerating Engineers at their annual meeting in December, 1914, and are incorporated in the Transactions of that society.

The measurements upon ammonia received the principal attention during the latter part of the year, and some of the results should be ready for publication early in the coming year. In particular, the measurements (*c*) of latent heat and specific heat of this substance are well advanced.

The thermal conductivities of insulating materials used in cold-storage construction are being determined in connection with similar measurements upon materials used for insulation in other ways, an investigation which is the subject of a special paragraph elsewhere in this report.

Among the works problems which called for investigation by the Bureau that of the presence of noncondensible gas in ammonia refrigeration systems received considerable attention. A preliminary report upon this subject was included in last year's annual report.

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 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.

The wide scope of these investigations requires the close cooperation of many of the laboratories of the Bureau. Thus at present the heat, weights and measures, electrical, concrete, ceramics, and structural materials laboratories are engaged on various phases of this work, such as the measurement of high temperatures, the design and construction of large furnaces for testing building panels and partitions, the fire tests of partitions built up of different structural materials, the determination of thermal conductivities and expansions of various structural materials, safety rules for electric wiring and problems appertaining to the national electrical code, etc., and the load-carrying capacities of structural steel columns under exposure to fire conditions when unprotected, partially protected, and fully protected by fireproofing coverings of different materials applied in various thicknesses and in the various ways commonly used in building construction.

This work serves as an excellent illustration of the broad scope of an engineering investigation that requires the cooperation of a number of the scientific and engineering laboratories of the Bureau.

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 with the Underwriters' Laboratories, of Chicago; the Mutual Laboratories, of Boston; and the Bureau of Standards. In the first series of tests are included over 70 structural-steel, reinforced con-

crete, and cast-iron columns. The columns will be tested in a specially designed furnace now nearing completion in the Underwriters' Laboratories in Chicago. The columns to be tested are designed for a working load of 50 tons. Each column will be placed in the furnace, a constant follow-up load of 50 tons applied by a hydraulic machine, and the column heated until it fails. The temperature in the furnace and in various parts of the column will be measured by suitable thermocouples; and the amount of deformation produced in the column during the test will be measured by means of a suitable apparatus which has been especially designed for this purpose.

The steel columns are of various types commonly used in building construction, such as rolled H, plate and angle, plate and channel, latticed channel, etc. Some of the columns will be tested unprotected, some partially protected, and others fully protected. The protective coverings are concrete, plaster on metal lath, clay tile, and gypsum tile. The protective coverings will be made from representative materials obtained from different parts of the United States.

Much of the necessary preliminary work of this large program of column tests has been done. It is expected that the protective coatings will be applied during the coming autumn and winter and that the actual fire tests will begin in the spring of 1916.

Thermal Efficiencies of Column Coverings.

Tests are under way at the Pittsburgh laboratories of the Bureau on the rate of temperature rise within cylindrical specimens of the various materials used for fireproofing building columns, with a view to supplementing and checking the results of the column tests. A special gas-heating furnace has been built for this work and a large number of cylinders of different materials have been prepared with suitable provision for inserting thermocouples axially, with their junctions at different distances from the heated cylindrical surface. Cylinders similar to the cylinder under test are placed at each end of the latter, in contact with its end faces, to minimize the disturbing effects of heat losses from the ends.

Strength of Steel at High Temperatures.

As a preliminary to the tests of the building columns, some tests were made upon steel tubes to determine the relation between the load they will support and the temperature to which they are heated. The ultimate compressive strength was measured by mounting the tubes in a testing machine, the tubes being heated quite uniformly by a suitably spaced electric heating coil wound over the outside and loss of heat from the ends being reduced to a minimum by asbestos disks. The temperature was measured by a thermocouple within the tube extending some distance beyond the center and then doubled back on itself to minimize the effects of conduction to the cooler ends. The behavior of such a tube may be expected to simulate closely that of a steel column. The tests were made primarily to obtain information as to what is to be expected in the much more elaborate tests of actual columns, and to serve as a guide in the design of the apparatus for those tests, especially the apparatus for measuring the temperatures of the columns. The results of these preliminary experiments seem to show that the protective covering on

a steel column, to be effective in a fire, must prevent the steel from reaching a temperature in excess of about 625° C. (1,150° F.).

More elaborate tests on small building columns are to be made in a special furnace built for such tests at the Pittsburgh laboratories of the Bureau.

Thermal Expansion of Structural Materials.

The weights and measures division has completed the designs for an oil bath and for an electric furnace which provide facilities for the determination of coefficients of expansion in the temperature range from that of liquid air (about —190° C.) up to about 700° C. The construction of these rather elaborate pieces of apparatus has been completed in the instrument shops of the Bureau and will be applied, as time permits, to the determination of the coefficients of expansion of structural steels, the samples to be tested being taken from different parts of the sections of large building columns and girders of known composition and elastic properties.

Panel-Testing Furnace.

During the latter part of the fiscal year the erection of a penal-testing furnace was begun, which will afford the best modern facilities for testing the fire-resisting properties of building partitions, the test panel being 12 by 16 feet in area. The equipment provided consists of an oil-burning furnace, with necessary boiler, blower, oil tank, etc., 5 massive structural steel frames into which the test panels are built, suitable trolleys, crane, structural steel panel rack, etc., to enable the built-in panels to be moved into position before the furnace, fire pump for applying the hose stream from a $1\frac{1}{8}$-inch nozzle on the heated partition under test, to simulate fire conditions, etc. This plant, when fully equipped with 7 additional panel frames, will cost about $15,000 and will be the most complete of its kind at present available. It is expected that fire tests can be started early in the coming winter. Steps will be taken to formulate a comprehensive program of fire tests of various building materials after consultation with representatives of the various engineering and technical societies and manufacturing associations interested in the manufacture and use of these materials.

Building Codes.

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.

Recommendations Concerning Fire-Resistance Investigations.

In the several preceding paragraphs there has been given a brief summary of the work of the Bureau relating to the investigations of the fire-resisting properties of structural materials. The data sup-

plied by such tests, however elaborate and comprehensive they may be, will only be utilized to their fullest advantage after they have been considered by all the numerous interests concerned and have been finally incorporated into State and municipal building codes. The goal toward which this work should tend, therefore, is to supply the necessary engineering data on which to base a much-needed revision of our building codes. With the appropriations at present available it is possible to undertake investigations on only a few of the important features of building construction. Hence, as shown by the foregoing summary, the present activities of the Bureau along these lines are concentrated on the tests of building columns and of building partitions. Many other important features of building construction should be made the subject of systematic investigations, such as floors, roofing, fire doors and shutters, and wired glass. To install a satisfactory equipment for testing floors under conditions of load and fire will require about as much more. Upon the completion of the panel-testing furnace now being installed, the Bureau will have a very complete plant that should be operated continuously during the next few years in order to obtain the necessary data on the many different materials entering into building construction. This work is necessarily expensive, as it involves the testing to destruction of full-sized specimens. With the present appropriation only occasional tests can be made and the present equipment, therefore, only very inefficiently utilized.

Not all of the equipment referred to above should be immediately provided. It is of great importance that one or more of the more important items be provided each year in order that the several lines of investigation can be carried along together, thus rendering possible the accumulation of the necessary engineering data to warrant a revision of our building codes within a reasonable time, say the next five or six years.

Along with the investigations referred to, a number of subsidiary investigations having an important bearing on building construction should be carried out, such as sprinkler systems, storage of inflammables, and temperature actually attained in various types of fires from field inspections and special laboratory tests.

In the last few years many public organizations have become active in a nation-wide campaign to reduce the present annual fire losses of a quarter of a billion dollars. The Bureau should do its part to assist in this great movement for National conservation.

To provide for the immediate requirements of this work, namely, the installation of the necessary facilities for beginning the fire tests on floors, fire doors, roofs, etc., and for the continuous and efficient operation of the large panel-testing furnace now nearing completion, it is recommended that the appropriation for this work be increased to $50,000 a year.

Fire Tests of Insulated Sheet-Metal Cabinets.

At the request of the General Supply Committee, the Bureau made a number of fire tests on insulated sheet-metal cabinets of the type that had been submitted to that committee for the award of contract for the ensuing year. The cabinets tested were 7 in number, the product of six different manufacturers, and were purchased on the open

market. The dimensions of the cabinets varied somewhat, but were about 6 feet by 3 feet by 2 feet.

The test was made by mounting the cabinet within a large gas furnace in such a way that the cabinet was exposed to the flames on all sides. Thermocuples mounted on the outside of the cabinet, but near its outer walls, and in the interior space of the cabinet, served to measure the temperatures. Paper and small pieces of wood were also placed on the shelves within the cabinet. The temperature, as recorded by the thermocuples in the furnace, was raised quite rapidly to 1,500° to 1,700° F. A temperature of 400° F., which is sufficient to seriously damage contained documents, was reached in the various cabinets in from 5 to 23 minutes after starting the fire in the furnace. After the tests the cabinets were taken apart and examined for details of construction, insulation, damage to contents, operation of doors, etc. A detailed report of the tests was sent to the General Supply Committee.

While one of the conditions of these tests, namely, exposure to fire on all six sides, was more severe than would be likely to prevail in an actual fire, this fact would not materially influence the relative rating of the several cabinets and it would not affect the conclusion that these cabinets do not afford sufficient protection to contained documents when they are used where the fire hazards are even moderately severe. In fireproof buildings, with steel furniture, and little combustible matter to support a fire, their use would be perfectly safe, but in buildings having wooden floors, furniture, etc., and sufficient combustible matter to support even a moderate fire for half an hour or so, most of these cabinets would not afford sufficient protection to contained documents.

In view of the fact that some of the cabinets included in these tests are extensively advertised by the makers as safe under the most severe fire conditions, and even as being approved by the Government, it seems probable that at least a part of the public may be misled into a false sense of security in using some makes of cabinets for the storage of valuable documents.

An examination of the cabinets after they were taken apart showed that in most cases there was only a thin layer of insulating material between the inner and outer sheet-metal walls, a thick layer of air being depended upon for thermal insulation. The construction of these cabinets seems to indicate that there is a very general misunderstanding as to the insulating properties of an air space. While it is true that the thermal conductivity of quiescent air is very low, yet under the conditions prevailing in these cabinets when exposed to high temperatures there is a very large amount of heat transmitted through an unobstructed layer of air by convective circulation of the air and by radiation through the air. The amount of heat thus transmitted can be very much reduced by a suitable insulating material.

In view of the very unsatisfactory conditions found as a result of these tests, a report was sent to each manufacturer whose product was included in these tests, giving in detail the results of the tests of his product and containing suggestions for improvement. The Bureau has since received communications from a number of manufacturers stating that a much-improved product had been developed and requesting that the Bureau make further tests along the same

lines, a request which it is hoped can be met if the present crowded schedule of work will permit.

Melting Point of Concrete.

The melting point of 11 samples of concrete that had been through the Edison fire was determined with a view to ascertaining the temperatures that had been attained in this fire, some of the concrete in this fire being in a condition which showed evidence of softening and flow.

Observations in Connection with the International Ice Patrol of 1915.

In connection with the International Ice Patrol of the U. S. Coast Guard cutter *Seneca*, the Bureau was represented on all the cruises of that vessel by one observer and on one of the cruises by two observers. Practically continuous records were obtained of the temperatures of the sea water, including a rather detailed study of the temperatures of the currents off the Banks of Newfoundland and vicinity, with frequent determinations of the densities of the sea water, 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. Work done on atmospheric nucleation with respect to the formation of fog, including measurements of corona and of total liquid contents of fogs, is described in another section of this report.

Testing of Heat and Thermometric Apparatus.

During the year 1,300 mercurial thermometers of various kinds were submitted for test, of which 1,190 were certified. Among those submitted, there were 278 ordinary calorimetric thermometers, 78 precision calorimetric thermometers, 17 clinical standards, and the remainder laboratory and special thermometers of various types and ranges from below 0° to 500° C., including 5 recording thermometers. About 1.8 per cent were received broken and about 2.7 per cent were broken in the course of testing.

Sixteen thousand five hundred and twenty-four clinical thermometers were submitted for test; of this number 14,929, or 90.4 per cent, were certified. The percentage of those rejected amounted to 9.6 per cent of the total number submitted; 0.8 per cent were rejected on account of defects in construction, 1.1 per cent because of too great difficulty in throwing back index, 0.4 per cent on account of retreating of index, 0.4 per cent were received broken, 0.5 per cent were broken in testing, and 6.4 per cent exceeded the limits of allowable errors.

In addition to the above, there were tested a total of 7 platinum resistance thermometers and 1 indicator for a platinum resistance thermometer.

Among the calorimetric tests made by the Bureau, 11 were for the heating value of fuel oils and bituminous materials, 2 of calorifiers (instruments for transferring a known amount of heat), 4 of gas calorimeters, 253 standard heat samples, 1 for the specific heat of linseed oil, and 1 for the determination of the water equivalent of a bomb calorimeter.

In the high-temperature laboratories there were tested 3 radiation pyrometers, 11 optical pyrometers, 1 absorption glass for optical pyrometers, 35 rare-metal thermocouples, 8 base-metal thermocouples, 6 thermocouples with pyrometer galvanometers, 3 pyrometer galvanometers, and 14 homogeneity tests of thermocouples.

Among tests involving the melting points of various materials, 9 were for fire brick, 11 for concrete material, 3 for high-temperature cements, and 3 for metals.

Besides the above testing, a number of special tests were made involving 3 fire tests of building stones, 6 determinations of the melting points of samples of ceresene, 1 determination of the melting points of samples of paraffin, 6 cold tests of rubber samples, several determinations of the freezing points of samples of fire-extinguisher fluids, 9 efficiency tests of refrigerators, and 30 determinations of thermal conductivities. Other special work carried on was the preparation of a special steel ingot, soft outside and hard inside; a study of the behavior of silicon carbide ware in air at 1,800° C.; the preparation of carbides in an electric furnace; a study of the temperature conductivity of bales of cotton; and the standardization of a pyrheliometer.

Almost every variety of industry and manufacturing interests is represented in the above summary of tests, as well as Government, State, and municipal bureaus and commissions, technical schools, universities, etc. Among the thermometers tested were included a number of working standards used by manufacturers to control the accuracy of thousands of thermometers put on the market; the clinical thermometers were tested for the several medical bureaus of the Government, State medical institutions, manufacturers, hospitals, dealers, physicians, and individuals; calorimeters were tested for the gas industries and State commissions; and standard heat samples were furnished to numerous industrial plants using large supplies of fuel. In the high-temperature tests of pyrometers, melting points, etc., are represented every variety of industry in which the control and measurement of high temperatures is an important factor in the product of the plant, such as iron and steel plants and allied industries, cement, gas, and ceramic plants; electric manufacturing companies; manufacturers of high-temperature measuring apparatus, tools, springs, axles, automobiles, etc.; as well as technical and university laboratories, etc.

Of the total work of testing done by the division of heat and thermometry, somewhat less than half is done for the various bureaus of the Government, the remainder for the general public.

Information Furnished, Reports, Etc.

An important feature of the work of this division has been the information that has been furnished by means of letters, and often quite complete reports, on subjects related to its lines of work. Several hundred such communications were prepared during the year. The requests for information came from nearly every type of industry; from manufacturers; National, State, and municipal laboratories and bureaus; from scientific investigators; from committees of engineering and technical societies; and from many others. The subjects treated were of every variety; for example, thermometry;

thermometer specifications; comparators for testing thermometers; thermoelectric pyrometers; cold junction corrections; optical pyrometers; radiation pyrometers; installations suited to particular requirements; calorimetry; heating value tests of gases; specific heats of liquids and gases; heats of combustion of gases; definition of the British thermal unit; melting points of oxides, fire bricks, ash, cements, etc.; refractory glazes; decomposition temperature of calcium carbonate; thermal conductivities of insulating materials, bricks, etc.; apparatus for testing thermal conductivities; testing of steel car sections; containers for molten oxides; tests of refrigerators; fire tests of insulated steel cabinets; baffle plates and burners; viscosity measurements; conversion tables; flash-point testers; resistance of pipes to the flow of liquids and gases; design of gas-burner nozzle; design of aeroplanes and windmills; windage of fly-wheels and steam turbines; ventilation; commercial separation of oxygen and nitrogen by air liquefaction; uses of liquid air; heat of sublimation of ice below 0° C.; rules for the computation of horse-power of hydraulic and steam turbines; and condensation of moisture on iron car roofs.

New Work and Equipment for Heat and Thermometry.

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 quickly and conveniently check the accuracy of their pyrometers, just as standard combustion samples now furnished by the Bureau serve to check heating value tests. Numerous requests have been received by the Bureau to furnish such standard melting-point samples. The necessary preliminary work to issuing such samples can be started as soon as funds are available for purchasing a sufficient supply of materials. The fees received for the standard samples would nearly, if not quite, pay for the work and materials.

A number of important items of equipment, which have been deferred from year to year, are urgently needed and should be provided for, such as electric furnaces, heavy current transformers and rheostats with the necessary special wiring, thermocouples, refractory porcelain for high-temperature work, bomb calorimeters, gas tanks, standard thermometers, and a new resistance bridge.

3. ELECTRICITY.

Weston Standard Cell.

Studies continue in progress on the Weston normal cell, the primary standard of electromotive force. The aim of this work, which has extended over a number of years, is to secure control over all the factors affecting this fundamental standard. Cells may then be constructed according to a definite procedure, such as to have a predetermined electromotive force accurate to a few parts in a million, and such as to continue unchanged indefinitely. The chief source of variation in the cell is the mercurous sulphate. It has been ascertained that this substance, when prepared by alternating-current electrolysis, gives very constant electromotive force, but different samples do not quite agree. The study of these differences is

actively in progress. It has been found that the preliminary washing produces negligible effect, while acid strength and temperature are important causes of variation. The effects of the rate of stirring and size of grain are under investigation, indications being that fine-grained samples give higher electromotive forces than the coarser-grained samples.

The type of standard cell used in ordinary electrical measurements, the unsaturated Weston cell, is under investigation as to its reproducibility and constancy. Such cells when set up with alternating-current mercurous sulphate were found to be very constant.

Mercury Standard Ohm.

The unit of electric resistance is defined by international agreement in terms of a specified column of mercury in a glass tube at the temperature of melting ice. Such standards have been set up at the Bureau, and the paper describing the work is in press. (See Scientific Paper No. 256.)

Silver Voltameter.

The international ampere adopted by the International Electrical Congress (London, 1908) as one of the two primary electrical standards is defined as the continuous current which deposits silver from an aqueous solution of silver nitrate at the rate of 0.00111800 gram per second, under certain conditions. The instrument used in making such deposits of silver is the silver voltameter. Many investigators have published the results of their experiments with this instrument, but at the time of the electrical congress much remained to be learned about it. The Bureau has actively prosecuted its researches in this subject for several years past and has published six papers on the subject. During the last year the Bureau has cooperated with Prof. Hulett, of Princeton University, who had previously made an extended study of various voltameter problems. The results of this work include the discovery of a hitherto unsuspected source of error in washing the deposits of silver. The Bureau's work and Prof. Hulett's work have now been brought into excellent agreement. (See Scientific Paper No. 240.) The last few months have been spent in an effort to determine the amounts of foreign substances deposited with the silver. These are commonly called "inclusions." A considerable number of deposits have been heated to over 600° C. both with a flame and in a furnace to expel these inclusions. The very concordant results which have been obtained indicate the inclusions to be about 0.004 per cent on the average when the electrolyte is pure. This Bureau has previously published 0.00111804 as the value it has determined for the electrochemical equivalent of silver by means of its voltameters and absolute current balance. The latest work on inclusions, mentioned above, now makes it appear that the value 0.00111800, the figure adopted by the London Electrical Congress, is the best assignable value for the electrochemical equivalent. On the above basis we are now able to compute anew the value for the faraday, which is an important constant in the science of physical chemistry. It is equal to 107.88 (the atomic weight of silver) divided by 0.00111800, which is 96,494 coulombs.

This value can not be accepted as settled, however, inasmuch as official specifications for the silver voltameter have not yet been agreed to internationally. It is probable, however, that the value 96,500 for the faraday is within a hundredth of 1 per cent of the true value expressed either in absolute or international coulombs; that is, coulombs defined in terms of the absolute or international ampere, which are numerically in extremely close agreement.

Inductance of Electrical Shunts.

A study has been made of the inductance of resistance standards such as are used in the measurement of large currents. (See Scientific Paper No. 246.) The ordinary methods can not be used for the measurement of such inductances, because these standards are four-terminal conductors of a special form. Two methods were devised for the purpose and were found to work well in the laboratory.

Simple Method for Testing Electrical Instrument Transformers.

A method was developed for testing instrument transformers by the aid of ordinary watthour meters, such as are used in buildings to measure the consumption of electrical energy. (See Scientific Paper No. 233.) Attempts to determine the ratio and phase angle of these transformers by using watthour meters in both primary and secondary circuits have not met with much success. The method here developed is to determine simply the difference between two transformers, one of them being a standard. It was discovered in connection with this work that commercial watthour meters are constant enough in their performance to serve as test instruments in this comparison, their variation in successive tests being surprisingly small.

Measurement of Earth Resistivity.

A knowledge of the electrical resistivity of earth is often necessary in connection with grounding electrical systems and in the study of the effect of stray currents in the earth. An improvement in the methods of measuring earth resistivity has been made by using four electrodes and considering the measurement to be that of a four-terminal conductor. The troublesome large resistances at the electrodes are thereby eliminated. A paper describing the method has been prepared.

Standard Air Electrical Condensers.

For some time there has been a need for better standard air condensers for use in the alternating current measurements at the Bureau. Such condensers consist of two sets of metal plates interleaved with one another, the two sets being electrically insulated from each other. It is very difficult to make them mechanically rigid. Great improvements have been made in this respect by a new design using quartz insulators. A number of the new condensers have been constructed, and are found to have a very constant electrical capacity. The capacity does not change with frequency of charge and discharge.

New air condensers have also been designed and constructed for use in radiotelegraphy. The plates have a spiral shape, such as to facilitate many of the high-frequency measurements.

Galvanometers.

One of the investigations in progress relates to the sensitiveness of galvanometers. These are used in various kinds of electrical measurements in which the accuracy or precision must be high; such, for example, as the comparison of resistance standards (on the values of which measurements of electrical power depend) and the measurement of temperature to 0.001° C. by means of resistance thermometers.

A paper on the general design of sensitive galvanometers has been prepared. The paper gives and discusses the mathematical relation 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 purposes.

For industrial purposes alternating current is largely used. This has necessitated the development of methods for testing alternating-current apparatus and as progress is made there is a demand for higher accuracy in the measurements. Where a high accuracy is required null or balance methods are usually employed and these require some kind of detector which will give a definite indication when an alternating current is passed through it. For certain classes of work a telephone receiver answers the purpose very well, but for alternating currents of low frequencies it is very insensitive. In such cases the vibration galvanometer is much more sensitive and is used to a considerable extent. In some classes of work, however, there is a need for a still more sensitive detector. By a careful study of the problem, making use of the experience gained in the construction and use of sensitive galvanometers for direct current, alternating-current galvanometers of high sensibility are being developed. The theory of the separately excited galvanometer has been studied and such instruments have been constructed and used. The performance of these galvanometers can be varied by changing the constants of the circuits to which they are connected. They can be made as sensitive as the best direct-current galvanometers, and are particularly useful in alternating-current bridge measurements. A scientific paper on these instruments has been prepared for publication.

Parallel-Decade Potentiometer.

An improvement in the accurate measurement of temperature has been made possible by a new potentiometer designed here and constructed during the spring. The small electromotive forces used in the thermoelectric method of temperature measurement can be measured with increased accuracy by means of this instrument. The settings of the potentiometer are varied by moving a high-resistance shunt from one set of coils to another. Thermal electromotive forces generated at the sliding switches do not materially affect the measuring circuit.

Circular on Electric Measuring Instruments.

Bureau Circular No. 20 has been thoroughly revised and brought up to date. This new edition was prepared with the cooperation of

a number of engineers and instrument makers and the meter committee of the National Electric Light Association. This necessitated a number of conferences and considerable correspondence. The circular presents the principles underlying the construction and operation of commercial electrical instruments, together with information concerning the advantages and limitations of the various types such as will assist the user to determine which general type is best suited to a given purpose. The design, sources of error, and the testing of electric instruments are treated.

Measurement of Conductivity of Electrolytes.

The electrical division cooperated with an investigator working under the Carnegie Institution of Washington in this research, the work being done at the Bureau. Most liquid conductors of electricity are electrolytes, and no satisfactory methods of measuring their conductivity have hitherto been perfected. To eliminate disturbing factors, one of the first requirements is a source of alternating current free from harmonics. Several types of generators were investigated, and one was found suitable. A satisfactory measuring bridge was developed. The conditions were found for eliminating the effect of change in voltage upon the measured conductivity. The effect of frequency of the measuring current and the effect of the type of electrodes were studied. Very high accuracy was attained in the final measurements.

Resistance and Inductance of Bimetallic Wires.

Wires made up of a steel core with an outer copper sheath are used in electric power transmission and in telephone work; having greater strength than copper wires, they can be used in longer spans. Accurate data on the electrical properties of these wires has been lacking. The resistance and inductance vary with the frequency of alternation of the current. Measurements of these quantities were made, and formulas and tables prepared, for the commercial sizes and grades of copper clad steel wire and iron telegraph wires. (See Scientific Paper No. 252.) In connection with the work, a study was made of the magnetization of an iron wire by a current flowing through it.

Magnetic Method of Determining Flaws in Steel Rails.

An examination of the possibility of detecting flaws in steel rails by a magnetic method has been in progress for some time. Two 15-foot sections of an 80-pound rail were used. Artificial flaws introduced into these specimens can be located by magnetic measurements made with large coils which are arranged to slide along the rails. This investigation is carried on in cooperation with the engineering division of the Bureau, the mechanical tests and magnetic tests being complementary. The results so far obtained indicate that the magnetic method of finding flaws in rails may possibly become commercially feasible, although much remains to be done in that direction.

Correlation of Magnetic and Mechanical Properties.

The investigation seeking to correlate the magnetic and mechanical properties of steel continues in progress. Data have been collected

on the magnetic and mechanical properties of several series of carbon and alloy steels after different heat treatments.

Magnetic Permeameters.

A thorough investigation of an important type of permeameter was completed during the year. (See Scientific Paper No. 228.) This is an instrument for measuring magnetic permeability, and has been extensively used in the past for commercial testing. This permeameter consists essentially of a magnetic circuit in which there is interposed a suspended coil carrying a constant current. A deflection of the coil is a measure of the induction through the specimen of iron under test. It was found that the indications of the instrument require corrections in some cases as large as 100 per cent. The correction is different for different grades of test specimens. It was concluded that with great care in its use, such a permeameter is capable of yielding results sufficiently accurate for commercial requirements.

A new permeameter has been developed at the Bureau. It is capable of measuring permeability with speed and accuracy. By its use it was found that some of the standard magnetic bars prepared by the laboratory five years ago were not sufficiently homogeneous. A new set of standard bars has been prepared, examined for homogeneity, and carefully measured for their magnetic constants.

Temperature Coefficient of Magnetic Permeability.

Magnetic tests of iron are ordinarily made without regard to the temperature of the specimen. When an accuracy of 1 per cent in the permeability is required, the temperature has to be considered. An investigation just completed has shown that temperature coefficients may be as great as one-third of 1 per cent per degree. A knowledge of this is important not only because room temperatures vary, but also because the bar of iron may be 10° to 20° C. higher in temperature than the room, owing to the heat developed in the magnetizing coils. The results of test on a given material can not be corrected to standard temperature by means of data obtained from other materials, because the temperature coefficient is different for different materials and even for the same material with different heat treatments. The only generally reliable way to avoid errors arising from the effect of temperature upon permeability is to regulate the temperature of the specimen under test. (See Scientific Paper No. 245.)

Core Losses in Iron at High Inductions.

One of the chief considerations in the design of dynamos and other electric power apparatus is the limitation of power loss due to heating in the iron. It is, therefore, of great importance to have an accurate knowledge of the behavior of iron when subject to magnetizations such as cause large losses of power. This has been the subject of special study for some time past. It has thus far been possible to extend the measurements from the former limit of 10,000 to 15,000 units of induction.

Magnetic Circular.

Bureau Circular No. 17 on magnetic testing has been revised and extended and will shortly be issued. The methods used at the Bureau are explained in detail. This information has frequently been sought in inquiries addressed to the Bureau. Information is given upon empirical formulas for approximate calculations of induction and core loss. Typical characteristics of ordinary commercial magnetic materials such as are used in electromagnets and permanent magnets are given. The circular is a valuable compendium of information on magnetism.

Radium Testing.

There has been a great increase in the volume of testing which the radium laboratory has been called on to do for the public. The apparatus for the testing of radium salts is being improved. The Bureau has been called upon to measure single specimens that contain nearly 16 times as much radium as the largest standard. To facilitate such work a set of lead filters has been carefully standardized. By screening the electroscope with lead plates, it has been found possible to measure satisfactorily a specimen containing 16 times as much radium as the standard. Further studies in connection with such measurements are being made. The method is not, however, so satisfactory as it would be if the laboratory possessed a supply of radium more nearly comparable with the large specimens sometimes submitted for test.

Increase in the Bureau's Stock of Radium.

An increase in the Bureau's stock of radium is needed. The Bureau should have a much larger standard of radium than at present. Large test specimens could then be standardized by a more direct comparison, and the present 15 milligram standard could be placed in the vault and retained with greater safety as a primary standard.

Alpha Ray Activity of Uranium Oxide Powder.

A study of the alpha ray activity of uranium oxide powder has thrown doubt upon the validity of such activity as a guide to the amount of radioactive material contained.

Radium Emanation.

Second only in importance to the study of radium salts is the investigation of radium emanation. Such work has been carried on throughout the past year. The equipment is being continually improved. An interesting auxiliary is a 1,500-volt battery made up of dry cells such as are used in flash lights.

Circular on Radium.

Part of the work of the radium laboratory is to act as a clearing house of information. Attention is being given to the indexing and abstracting of the literature on radium. A circular is in preparation, 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 radium or the allied substances in any way.

Radio Communication.

The radio laboratory has assisted the Bureau of Navigation of the Department of Commerce with technical information from time to time, and has designed, tested, and adjusted instruments used in examining the radio equipment of ships by the inspectors of that Bureau.

Radio Sets for Lighthouse Tenders.

Five complete radio equipments for the Bureau of Lighthouses were designed and their construction supervised by this laboratory. They are installed on lighthouse tenders and are provided with a number of special features adapted to the needs of the lighthouse service. As a result of the attention given to the design of these sets, they were purchased at a smaller price than the usual commercial sets of the same range, and are much more efficient in the service for which they are intended. In the development of this equipment, valuable experience and information were gained which could hardly have been obtained in any other way. The tenders equipped with radio apparatus will be of greater service in promoting safety at sea than ever before. Being at no time cut off from communication with the lighthouse or with ships, they will be a much greater aid to navigation.

Radio Interference.

An investigation was made of a case of alleged interference caused by a large power arc operated by a commercial company, at the request of the Bureau of Navigation. Other companies and the Navy Department complained that this company was sending out wave lengths not allowed to it by law, such as to cause troublesome interference with radio messages from other sources. The company claimed that it was sending only wave lengths within the legally prescribed limits. A study of the waves actually used by the company showed that while the main sending wave length was as the company claimed, the apparatus gave rise to subsidiary and shorter waves which caused the trouble. It has not heretofore been recognized that arc generators may send out reinforced harmonics of the fundamental wave in such volume as to cause interference.

Promotion of Safety at Sea.

Some improvements in radio apparatus are being developed which will be of assistance particularly to those branches of the Government having to do with the protection of life and property at sea. One of these is a fog-signaling device. With such a device automatically sending out radio waves, either on a ship or at a lighthouse, other ships could navigate in a fog with greater safety. Another device which if successful would be of great assistance in navigation is a direction finder. This relatively simple apparatus permits the operator of a radio set to determine from what direction a message is being sent. This should be of great advantage, especially in emergencies. The device is under study.

Design of Inductance Coils for Radio Work.

A study has been made of the practical design of inductance coils for use in high-frequency circuits, such as wave meters, receiving

tuners, and transmitters. The inductance coil is one of the two most important elements of a radio circuit, and information as to the proper design of such coils is being continually sought by the manufacturer and user of radio apparatus. A number of coils have been received from manufacturers, colleges, and Government departments, and tested at frequencies ranging from 50,000 to 1,000,000 cycles per second.

Proposed Work in Radiotelegraphy.

A number of additional lines of work in radiotelegraphy have been either begun or planned for the coming year. The design of radio apparatus is at present limited by lack of precise data on the high-frequency resistance of conductors of various forms. Investigation will, therefore, be made of the resistance of straight wires and strips and coils of various shapes, wound with various kinds of wires, and mounted in various ways. Of like importance is new data on the dielectric losses in various types of radio condensers. The methods of measuring resistance, current, and wave length at high frequencies are being studied.

Information as to the behavior of different types of antennas is urgently needed. At present the ground resistance, radiation resistance, and other characteristics of various types of antennas can not be determined with great accuracy. The methods of measuring resistance and capacity of antennas should be studied, together with the question of the dielectric and hysteretic properties of the soil. Permanent towers are needed, upon which experimental antennas can be mounted, so that the problems now in hand and others which will arise may be adequately treated.

The use of radiotelegraphy by this Government to promote safety and as an aid to navigation has been by no means as thoroughly developed as it might well 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 to such as are engaged in the protection of life and property at sea. Such assistance may take the form of information upon the technical possibilities of radio instruments and equipment, the standardization of apparatus, and the adaptation of radio equipment to the particular needs of a given service.

Additional Facilities Needed in Radiotelegraph Work.

The increasing requirements of the radiotelegraphic work, as to space and experimental facilities, necessitate a separate building. Auxiliary to the building there should be two towers about 150 feet in height for the support of experimental antennas. The building would house not only the radio laboratory of the Bureau but also those of the Army and Navy, now located in a few of the rooms of the Bureau laboratories. Considerable work has been done in the Bureau laboratory, as has already been outlined on preceding pages, but the rapidly increasing importance and range of radiotelegraphy demands a considerable extension of the work, for which the present space and facilities are quite inadequate. Not alone the design of radio apparatus and the assistance of other bureaus in securing suitable equipment, but a thorough study of the scientific principles underlying the art, are urgently needed. An appropriation of $50,000

for a building for this work has been requested. This request is renewed. An increase from $10,000 to $20,000 of the appropriation for apparatus and for assistance in connection with the radio work is also desired. The Bureau of Standards is an ideal place for the location of a well-equipped radio laboratory. The close proximity of the radio laboratory to the other scientific and instrumental resources of the Bureau would be a distinct advantage. The building would be two stories in height, would be located south of the electrical laboratory, and would be connected by means of a tunnel with the other buildings, so that all the generators and other facilities of the Bureau would be directly available.

Effect of Atmospheric Conditions on Flame Standards of Candlepower.

In the pursuit of its plans for putting tests of gas on a more exact basis, the Bureau found it necessary some years ago to make a special study of the flame standards of candlepower which are used for such tests. In order to be able to calibrate such lamps accurately at all seasons of the year a precise knowledge of the effect of atmospheric conditions was necessary, for variations due to these conditions may be as great as 20 per cent. Thorough determinations of the effect of humidity were made, the results of which have been confirmed by all the more recent tests.

In order to certify the candlepowers which the standards would have in cities at different altitudes, however, it is necessary also to know the effect of changes in barometric pressure, and the natural variations in pressure in Washington were not sufficient to determine this effect over the required range. A set of tanks was therefore constructed in which the lamps could be supplied with the proper flow of air at a high or at low pressure, while the corresponding candlepowers were measured by a suitable photometer.

Such measurements have been made on the best types of standard lamps and also on the types of gas burners most commonly used in tests. The same apparatus has been used for exact determinations of the effect of humidity on the gas flame, which has never before been made. This work is now ready for publication, and will show more fully than has heretofore been done the real significance of the results of tests of gas under various conditions.

Photometry of Lights of Slight Color Difference.

The tendency in recent developments of lamps has been continually toward the production of whiter light, so that exact comparison with the older standard lamps to which all our measurements must be referred becomes increasingly difficult. The work done last year in determining the equations of curves showing the changes in candlepower and efficiency of tungsten lamps when the voltage is changed has been published in Scientific Paper No. 238, and the results have been widely used in lamp factories. Another paper, dealing particularly with certain peculiar difficulties which arise in the measurement of the new gas-filled incandescent lamps, has been prepared for publication.

All measurements of lights differing in color from the fundamental carbon standards have hitherto been essentially unsatisfactory, for

two reasons—in the first place it is very difficult for any one to judge when equality has been obtained in the photometer, and hence the results vary erratically; in the second place, when enough measurements have been made to average out these erratic variations there still remain differences between individuals. In other words, the candlepower really is different for different observers, and the proper value to assign is that which the average person would get.

It is hardly justifiable to assume that the few men in a laboratory fairly represent the average of people in general unless some test has been made to show their relation to that average. Such tests have recently been devised, but have not been sufficiently well tried out to be generally adopted.

The Bureau (in cooperation with the research committee of the Illuminating Engineering Society) has planned an extensive investigation to consist of (1) the establishment of average values by having 100 or more observers make measurements on certain colored lights; (2) a test of the proposed method of choosing observers who properly represent the average thus established; and (3), if the method proves to be practical, the calibration of colored glasses, solutions, multivoltage standard lamps, and other devices which are used to obviate the difficulty due to color. This work is just being started and is to be prosecuted as actively as possible during the summer, while the amount of routine testing is small.

Illuminating Engineering.

Provision is needed to enable the Bureau to take up in an adequate manner some of the most urgent problems in illuminating engineering that concern municipalities. The lighting of streets and public spaces, public buildings and auditoriums, stores, factories, and private homes is a matter that is receiving a great deal of attention in recent years, and a great many new and improved methods, as well as fixtures and appliances for the purpose, have been developed; but reliable information as to the value of much of this material is hard to obtain.

The claims made by manufacturers are often conflicting, and there is a great need for an unbiased agency, such as the Bureau of Standards, to make photometric and other tests and to determine the performance of the appliances that are on the market. For the use of the Government, States, and cities alone such information would be of great value, but it would also be of immense value to the general public, and particularly to architects and contractors who are specifying and purchasing such appliances. We know also from tests which we have made that improvements at practically no cost could often be made if the necessary information were available. The subject is a highly technical one and directly in line with the Bureau's work, and a moderate appropriation would yield valuable results.

During the past year information has been collected regarding street lighting from a large number of cities, and it is expected that a careful study of this data will furnish results of interest to many cities. Some of the experimental work done is mentioned under the heading "Photometry."

Electrical Testing.

Standards, instruments, and materials are tested by seven sections of the electrical division. In the following enumeration, the more important tests for the Government are so indicated.

Standard cells and resistance apparatus.—Tests were made during the year on 74 Weston portable cells, 6 Weston normal cells, 1 Carhart-Clark cell, 11 precision rheostats, 5 potentiometers, 8 volt boxes, 9 wheatstone bridges, 12 resistance standards for current measurement, 83 precision resistance standards, and 99 wires and cables for conductivity measurement. Of the last item, 95 were for the Panama Canal.

Capacity and inductance.—The tests for capacity and inductance included 17 electric condensers, 6 inductance coils, 2 measurements of inductance of resistance coils, and 7 insulation resistance tests. A test was made of the dielectric constant of some varnished cambrics for use in a high-voltage transformer. It was found that the apparent dielectric constant varies with the air space in the condenser in which the material is used. The effect increases with the heterogeneity of the dielectric.

Radium.—There were tested by the electric division during the past year 82 specimens of radium and mesothorium. These specimens, 14 of which were for the Government, aggregated 2.127 grams of radium, valued at $254,000. One large test was of 250 miligrams for Italy, for use in hospitals and laboratories there. Some of the specimens in this lot were found to be mounted in a slightly defective manner; this case is an example of the service which the Bureau frequently renders by pointing out defects in standards as well as testing them. There were also 3 tests of emanation of radioactive water, 11 standard solutions and emanation standards, and 2 samples of radioactive material. The last was a special test for the Department of Agriculture.

Electric measuring instruments, etc.—The following tests were made for the public: 14 voltmeters, 22 ammeters, 13 wattmeters, 30 watthour meters, 18 voltage transformers, 32 current transformers, 2 special transformers, 12 samples of wire, 5 samples of tape, 6 pairs of rubber gloves, 2 recording potentiometers, and 8 dielite cylinders. The following articles were tested for the Government: 7 voltmeters, 4 ammeters, 2 wattmeters, 3 watthour meters, 1 current transformer, 15 motors, 35 dry cells, 16 samples of wire and cable, 38 samples of tape, 1 sample of varnish, 2 samples of sheet insulation, 34 transformer coils, 150 pairs of rubber gloves, 15 porcelain insulators, 1 glass insulator, 4 electric "healing" devices, and 37 electric fans. The electric fans were tested for the General Supply Committee. Measurements of air delivery and relative efficiency are used by the General Supply Committee in awarding the annual contracts for electric fans.

Magnetism.—Magnetic materials tested during the past year included 69 samples of iron for measurements of normal induction, 21 determinations of hysteresis, 51 core loss measurements, and 3 miscellaneous magnetic tests.

Photometry.—1,253,504 electric lamps were inspected and 3,141 lamps life tested for the various Government departments; of the

former 692,745 lamps were tungsten and the rest carbon, and of the latter 2,400 were tungsten and the rest carbon. Other tests for the Government were 86 reflectors and globes, 4 spherical reduction factors of electric lamps, 30 samples of kerosene and signal oils, 2 portable photometers, 1 illuminometer, 1 comparison of illumination from motion-picture machines, 1 test of acetylene signal lamps, and 21 gun-sight lamps. The following tests were made for the public: 140 incandescent lamps tested for candlepower, 2 color screens, 11 pentane lamps, 1 hefner lamp, 1 sample of pentane, 1 retinal sensivity tester, 2 luminous arc lamps, 1 kerosene mantle lamp, and 4 luminous-flame oil lamps.

Besides routine tests of lamps, reflectors, photometers, etc., the following tests of special interest have been made. Samples of the two most widely used types of "luminous arc" lamps for street lighting were tested to determine their efficiency, the distribution of the light, and the life of the electrodes. Comparative measurements of the illumination furnished by several kinds of motion-picture machines were made as a basis for the choice of a type of which a large number were to be purchased by various Government departments. An acetylene signal lamp used by the Coast and Geodetic Survey for long-range triangulation was tested and experiments were made to show the great increase in intensity which could be gained by using a concentrated filament electric lamp instead of the acetylene flame. A kerosene mantle lamp was measured in comparison with luminous flame lamps and found to give about four times as much light for a given consumption of oil. Photometric tests of kerosene oils have only recently been begun by the Bureau; this year 30 samples were tested for the Government following the procedure outlined in the specifications. The specifications are not sufficiently definite in many respects, and when possible the tests have been made under different conditions to determine the effect of various factors not sufficiently well defined. Although kerosene is the illuminant used by more people than any other, its effective use has received comparatively little study, and considerable effort might profitably be expended in determining the properties of the oil which affect its illuminating value.

Among the photometers calibrated was one to be used by the Public Health Service in studying illumination in factories and in some of the Government offices. Another photometer, which was tested for the Weather Bureau, was fitted with reducing screens and color screens to extend the range of the instrument so as to make possible measurements of intensities up to that of direct sunlight, while a third, intended for the Bureau's street-lighting investigations, was fitted with absorbing screens to make possible the measurement of illumination in poorly lighted streets; the extreme range covered by these instruments was such that the highest illumination measured was about 1,000,000 times the lowest.

The life tests made on incandescent lamps supplied under Government contracts showed that the quality of these lamps is being steadily improved, so that although the requirements of the specifications have been materially raised in the last year nearly all the lamps supplied to the Government passed the life requirements by a considerable margin. The advantage gained by conducting these tests

is well illustrated by the results of a test made by the Bureau on lamps supplied by contractors to the State Hospital of New York, where tests are not regularly made. It developed that the lamps which were being supplied were decidedly inferior to those which the Federal Government obtains. A few tests of the life of lamps were also made for private parties in cases where circumstances made the tests of sufficient importance to justify the work being done here.

Considerable time was spent on a test of gun-sight lamps for use in the Navy. This included a determination of the best intensity for such use and a test of several types of lamps made up for trial. A satisfactory form was finally obtained, and specifications for it formulated.

Radio instruments.—Tests of radio instruments included 5 wave meters, 5 inductance coils, 1 variable condenser, and 10 decremeters, 5 of which were made for the Government.

The above list of tests does not include a considerable number of magnetic tests, tests of Weston cells, etc., made for various laboratories of the Bureau.

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 replying to particular requests. Some instances from the correspondence of the electrical division during the past year may be given.

A great many inquiries regarding radium and radioactive preparations were received and answered. The subjects included the testing of therapeutic preparations, water activators, etc. The correspondence shows the need of a circular of information on radioactivity. This has been in preparation and will shortly be issued.

The Bureau is a repository, not only of scientific, technical, and commercial standards, but also of exact information in regard to units and standards. Compilers of physical tables seek such information from the Bureau. Material on units and electrical data were furnished for new editions of two books of tables during the year.

A variety of information has been furnished on the subject of radiotelegraphy. Suggestions for research, bibliographies, data on design and performance of coils, and particulars regarding the practical details of radio stations were among the information supplied.

Valuable service has been rendered by preparing opinions as to the technical worth of certain fraudulent devices. One of these was a primary battery alleged by the inventor to have extraordinary efficiency. It was supposed to be such an economical source of energy as to be superior to dynamos for the supply of electric heat, and could be used for the heating of houses. These claims have been used to extract large sums of money from the public. An inspection of the battery and a few simple tests showed that the claims amounted to a contradiction of well-known laws of nature, and that the battery is in the ordinary class of batteries such as are used for door bells and signal systems. In such cases, the Bureau cooperates with other branches of the Government concerned. Sometimes the case

leads to court processes, and sometimes to postal fraud orders. Another class of electric fraud embraces a number of devices supposed to cure diseases or otherwise benefit the human body. Several of these were submitted and examined during the year. "Electric" and "magnetic" rings and other appliances for the cure of all bodily ills have had a vogue for many years, and it is extremely difficult to eradicate them. Possibly a public statement as to their utter absence of electric or magnetic action will be of some assistance in discrediting them.

Public-Utility Investigations.

The electrical work so far mentioned has to do with the determination and maintenance of electrical standards, the investigation of methods of measurement, study of the electrical properties of materials, the design and improvement of instruments, and the testing of instruments and materials, all of this being done in the fields of electricity, magnetism, and photometry.

Another large and important field of work, some of which has more of an engineering character than most of the 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 scientific and engineering research, the study of public relations questions, the preparation of specifications regarding the quality of service, methods of testing and inspection employed by municipalities and commissions, safety rules for use by the utility companies to safeguard their employees and the public, and the collection and distribution of information by published papers and through correspondence.

Service Standards for Illuminating Gas.

This work has been carried on for several years under the direction of the electrical division, with the cooperation of the other divisions of the Bureau, especially the chemical and heat divisions. Regulations for gas service, as made by cities or State commissions, include among other things the requirements as to meter accuracy and the testing of meters, the specifications of the heating value or candlepower of the gas (or both), the degree of chemical purity as expressed by the limits set to the amounts of sulphur and ammonia that are permitted, the variations in pressure that may be allowed, and the manner and frequency of tests to determine whether the operating companies conform to the requirements.

In addition to investigations carried on by the Bureau for the past five years on this subject, which have resulted in a considerable number of papers published in the Bureau's scientific and technological series, a careful study was made of the rules and regulations of cities and States, and a thorough discussion made of the subject in Bureau Circular No. 32, first published four years ago. This was revised and republished two years ago and a third edition has been prepared and published during the past year. This publication has had a wide circulation and serves a most useful purpose in setting forth the proper basis for regulations; it also discusses the relation between the quality of gas and the efficiency of manufacturing processes, and the most satisfactory terms in which to specify gas quality and methods of testing.

This circular also contains model ordinances for the use of cities which control their own utilities, and state rules suitable for the adoption of State commissions which fix the standards of service for all the companies of a State.

In the original preparation of this circular as well as in its subsequent revisions the Bureau has had the cooperation of the gas industry, a special committee of the American Gas Institute having read the manuscript and offered suggestions. Many engineers of cities and commissions also gave similar assistance.

The advantage of having such cooperation between representatives of the industry, of the public, and of a disinterested national institution that is possessed of ample experimental facilities is obvious. It results in rules and requirements that are more nearly just and adequate, gives to the public greater confidence in the service of the utilities, and makes recourse to the courts much less frequent.

Another publication issued during the year is Circular No. 48, which gives a detailed technical discussion of methods of gas testing. This was the joint work of several divisions of the Bureau.

The Bureau has given assistance to a considerable number of State commissions and cities in connection with the adoption of ordinances or orders regarding gas service, and has sent a representative to a number of public hearings conducted by State commissions during the year. It is of much importance that the regulations and requirements of the several States and cities shall be as uniform as consistent with progress and justice to the companies and the public. The Bureau aims to serve in some measure as a clearing house of information on many of the scientific and public relations questions arising in connection with the regulation of gas companies, and to be perfectly impartial as between the companies and the public.

Electric Light and Power Service.

During the past two 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 be shortly published as Bureau Circular No. 56. 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 the same 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, many valuable criticisms and suggestions having been received after reading the manuscript. The Bureau has cooperated for years with the meter committee of the National Electric Light Association, and one of the important subjects of the new circular is meter testing and meter accuracy.

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.

Cooperation with the Underwriters' Laboratories.

Another question now being studied came to the Bureau because of its relations with the Underwriters' Laboratories. The Bureau cooperates with the Underwriters' Laboratories in some of its work, and had 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 renewable cartridge fuses, a device for protecting electric circuits. The Bureau is making a thorough investigation of various types of approved nonrenewable fuses as well as the renewable fuse under discussion, and is examining fuses as they are used. It is also conferring with insurance and municipal inspectors and engineers who have had experience with various types of inclosed fuses. Some of the experiments are being made in the Bureau's laboratories, and others in power stations where a large amount of power is available for the larger sizes of fuses. Some of these tests are to be made in conjunction with certain of the fuse manufacturers. When the question is decided and a report rendered, a full digest of the experiments and all the evidence gathered will be published, 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.

Electrolysis Mitigation.

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

The Bureau has been studying the question for the past five years and has done a large amount of work in connection with it. This has included laboratory investigations concerning the effects of electric current on concrete and 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 and the results obtained; field studies in actual practice with the application of remedies and a determination of the cost and results obtained.

During the past year some additional work was done in St. Louis and Springfield (Ohio) and a very complete report prepared on the survey made at Springfield, Mass.

This survey was made at the invitation of the city of Springfield, and most of the public-utility companies of the city, including the gas, electric-light, telephone, and telegraph companies. The railway company did not unite in the invitation, but gave the engineers of the Bureau free access to its property and full information regarding its current, cables, and station operation. The cost of the survey and the report is borne in part by the Bureau and in part by the utilities. The object of the work is not merely to benefit Springfield, but to demonstrate the method of procedure in making electrolysis surveys, and in securing relief from electrolytic corrosion in an efficient and economical manner. A complete electrolysis survey was also made in Altoona, Pa., and a full report thereon submitted to the city and utility companies.

Another phase of the electrolysis work is the studying of the various methods of bonding rails at joints so as to provide good conductance for the electric current flowing through the rails. The three aspects of these joints which are most important are their permanence, their conductance, and their cost. A very thorough study of

the subject has been made and a full report is being prepared for publication. In this work the Bureau has had the full cooperation of many of the electric railway companies and the manufacturers of rail bonds.

Still another phase of the subject is the question of roadbed resistance, since the amount of electric current flowing away from the tracks is reduced when the electric resistance from rails to earth is increased. In order to get definite information to aid the Bureau in making recommendations to railway companies, a number of sections of roadbed have been constructed on the Bureau grounds, and their resistance measured from time to time.

The work of the Bureau on electrolysis has been received most favorably by many railway officials and engineers, but very many still feel that it is a hardship to provide adequate conductors for the return current, having for so long been accustomed to turning it loose in the earth to return as best it could.

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 prepared, to be 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 will be continued and specifications 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. Additional papers prepared for publication during the year included Electrolysis and its Mitigations (Technologic Paper No. 52), Report on Electrolysis Conditions in Elyria, Ohio (Technologic Paper No. 54), and Report on Electrolysis Conditions in Springfield, Ohio (Technologic Paper No. 55).

National Electrical Safety Code.

The Bureau has been engaged for two 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 important 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. One of the four parts of the code, namely, the part containing the rules to be observed in the operation of electrical equipment and lines, was published as Bureau Circular No. 49 nearly a year ago and republished last May

after revision with the cooperation of the National Electric Light Association and many electrical companies and engineers of commissions. The other three parts of the code, in preliminary form, were published as Bureau Circular No. 54 last April after several manuscript editions had been successively revised and rewritten. Representatives of the Bureau have held conferences in many cities on the subject, extending from Boston to San Francisco, and have collected an immense amount of information and criticism which is now being used in the revision of the code, preparatory to a second preliminary publication. In the near future there will be held in Washington a national conference on this code; delegates will attend from the various engineering societies, several of the State commissions, a number of the larger cities, insurance interests, the National Council of Safety, and a delegate from each of the groups of engineers with whom we have held conferences in the various cities. This will be a very representative gathering, and it will be asked to discuss, amend, and approve the national electrical safety code, which by the time it is presented for discussion will probably have undergone more thorough study and discussion than has any similar set of rules before being adopted by an administrative body.

National Gas Safety Code.

The Bureau is also engaged in the preparation of a national gas safety code, along the same general lines as the electrical code, and is receiving the cordial support of the gas industry. This work has been taken up more recently and has not progressed far enough to publish more than an outline. The safety code will consist of five parts, as follows:

1. The manufacture of gas.
2. The distribution of gas.
3. The design, construction and testing of gas appliances.
4. The piping of buildings and the installation of fixtures and appliances.
5. The use of gas and the care of appliances.

The first two parts of the rules will apply to the gas companies and their employees; the third to the manufacturers of gas appliances; the fourth to plumbers and gas fitters and the inspection department of cities; the fifth to the users of gas, domestic and industrial.

There can be no question as to the great need of such a safety code, and we have every reason to expect the fullest cooperation of all the interests affected in its preparation.

Telephony.

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 and hopes to develop it in an adequate manner. Telephone standards need to be fixed and facilities provided for making tests whenever required by cities or public service commissions, as well as when requested by telephone companies or by manufacturers of telephone apparatus and equipment.

On the plea of public convenience and necessity for interchange of service, petitions for physical connection between telephone sys-

tems under different ownership, whether operated in different localities or in the same locality, and even cases involving the connection between intercommunicating systems in hotels, business establishments, etc., with one or both local operating companies, are being brought before public service commissions with increasing frequency. One of the questions involved is whether, if such physical connections were granted, the transmission of speech between telephones of the two systems would or would not be impaired by such connections in comparison with the transmission between two telephones of the same system. This question, as well as the more general question of what is proper and adequate service under given conditions, and many others, are susceptible of experimental study, and the representatives of the public should have facilities for such tests available, and competent and experienced persons to make the tests.

The Bureau will cooperate with manufacturing and operating telephone companies and telephone associations, as well as with State commissions and city officials, in this as in other public-utility work.

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

In some States there are no public-service commissions to issue regulations or inspect the quality and safety of the service rendered by the various utilities. In some other States the railroad or public-service commissions have taken no action in the matter, although having authority to do so. In either case the cities and towns must look after their own interests, 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, still 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 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 of Standards have been directed toward simplifying this problem by providing well-defined specifications of what constitutes good service, and the Bureau has a considerable correspondence with commissions and cities on this subject. The resources of 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 been taken up at all.

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. One method of doing it is for the States and cities to get together and establish a special bureau or institution for the purpose, the several States and cities paying for any service derived therefrom. The new Utilities Bureau of Philadelphia is such an institution, and there is ample field for its activities. But it has appeared very desirable for a bureau of the Federal Government to do a certain portion of the work; hence, the Bureau of Standards has been doing this 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, including a special appropriation for the safety work, is $40,000 per year, and allowing for the supervision and assistance rendered from the general funds it may be considered as $50,000 per year. 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 two billion dollars 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 four million dollars 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 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 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), would 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 is a reasonable estimate of the possible value of the service we are considering, assuming such service to be efficient and ample. One cent a year per capita does not seem too much for the people to spend through the Federal Government to accomplish this result. At present the Bureau of Standards is spending 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 develops until each person in the country was contributing, say, only one-fourth of a cent per year, and the total was one-fourth of a million dollars, 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 appraise 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 means of doing it equitably and effectively, are almost helpless.

4. OPTICS.

Determination of Standard Light Wave Lengths.

The determination of standard wave lengths has been continued throughout the year. The growing importance of spectroscopic analysis adds importance to this work and the need of standard wave lengths will be illustrated in the following paragraphs. During the year 131 standard wave lengths in the iron spectrum were published in Scientific Paper No. 251. The region covered in this publication extends from wave length 2,850 A to 3,700 A, all in the ultraviolet (1 A=0.0000001 mm.). The work on the visible portion of the iron spectrum is well under way and will soon be ready for publication. Owing to their extreme sensitiveness to red and infrared, photographic plates which are prepared at the Bureau will enable us to carry these investigations far into the infrared.

The prosecution of this piece of research necessitated the installation of a concave grating, apparatus for sensitizing photographic plates, apparatus for depositing metallic films cathodically, and the addition of considerable other laboratory equipment. Aside from supplying half-silvered mirrors for interference work, the cathodic apparatus has been useful in coating galvanometer mirrors with

platinum, and in plating mica with platinum for constructing a special condenser. Another by-product of this research was the determination of certain wave lengths in the neon spectrum. (See Scientific Paper No. 251.)

Information Furnished on Spectroscopic Subjects.

The spectroscopic information furnished to Government bureaus and to firms and individuals has been of quite a varied nature. In most instances this information could be given at once, but in the following cases some investigation was necessary. A suitable source for violet and ultraviolet light was found for the Bureau of Chemistry. The detection of minute quantities of impurities in ammonia by spectroscopic means was investigated at the request of the division of chemistry. The purity of electrolytic iron was investigated for the metallurgical division. This investigation led to the correct indentification of certain lines in the iron spectrum which are due to impurities. It also showed the extreme difficulty of obtaining iron entirely free from manganese, copper, and silicon.

Investigation of Vacuum Tubes of the Rare Gases.

For this investigation quartz vacuum tubes with sealed-in electrodes were furnished by the Cooper-Hewitt Electric Co., and filled either at this Bureau or by Sir W. Ramsey. The investigation showed that the spectra of these gases have not been determined with sufficient care, and a more extensive study of these spectra will be necessary before the purity of the gases can be proven. It is certain that Xenon is seldom, if ever, free from Krypton, and, conversely, Krypton probably contains Xenon.

Quantitative Spectroscopic Analysis of Steel.

This subject was investigated at the request of various manufacturers of steel. At present, in the judgment of the majority of eminent spectroscopists, the quantitative spectroscopic analysis of steel can be made only by an experienced observer at the expense of great labor and the exercise of much patience. An attempt has been made to bring the subject within the scope of the average analytical chemist and to increase the accuracy of the results. The results to date are quite encouraging. The preliminary work is rather large, but once it has been done the labor of analysis is not great. Consider a single simple example, the estimation of the chromium content of a low-carbon steel. Leaving the other constituents of the steel essentially in the same proportions, samples are made up, or selected from stock, having a chromium content of 0.02 to 4.00 per cent, each sample having about 25 per cent more chromium than the one before. The spectrum of each of these samples is photographed, and the comparison of a photograph of the spectrum of the unknown with this series permits an estimation of the chromium content to be made with some accuracy. In the case of the elements niobium and molybdenum, the estimation of small quantities by spectroscopic means is more reliable than the chemical analysis. In general, the spectroscopic rivals the chemical analysis wherever the element in question is present in quantities less than 5 parts in 10,000.

Spectroscopic Analysis of an Alloy which is Liquid at Room Temperatures.

This unique alloy was sent to the Bureau for analysis. The chemical analysis proved to be very difficult and a spectroscopic examination was made at the request of the chemical division. The sample was found to consist of gallium, indium, and zinc. It contained no mercury nor cadmium. In the course of the investigation, the spectra of the rare elements gallium and indium were found to be incorrectly determined and a redetermination, using purer material than has been hitherto employed, is greatly to be desired.

Spectroscopic Tests.

The ultra-violet transmission of two absorption cells was determined for the Weather Bureau. The performance of a spectroscope was investigated for the Bureau of Chemistry. Tests of the ultra-violet transmission of samples of glass have been made for various manufacturing firms.

Standardization of Industrial Sugar Testing.

The absence of standardized methods of testing sugars and sugar products has long been a handicap to the industry. The values of the materials tested make it necessary to secure the most accurate tests possible. Owing to the lack of a central standardizing bureau in the Western Hemisphere, the industrial concerns were for many years thrown entirely upon their own resources to obtain methods of testing. Hence, a diversity of methods of testing existed, not only among the companies doing business in the United States, but also between this and other countries with which the United States does a large import business. The Bureau has, therefore, increased its efforts toward securing the adoption of standardized methods where experts are in disagreement as to the best methods, and then to make these standardized methods available to Central and South American countries. Circular No. 44, on Polarimetry, has been issued. The interest aroused is shown by the demand for this publication, not only from this country, but also from all parts of the world. The first edition was soon exhausted and the work of revising for a new and more complete edition is now in progress

Conference of Polarimetric Experts.

The work of obtaining standardized methods of sugar testing would be greatly facilitated by calling a conference of the scientists interested. It has been suggested that if such a conference could be brought about it would be possible to secure an agreement on important methods which have long been in dispute. The Bureau hopes to take the initiative in this matter during the coming year.

Constants of the Saccharimeter.

Several years ago an investigation of the reading of chemically pure sugar on the scale of the saccharimeter (a polariscope for testing sugars) was undertaken. This is of fundamental importance, since this reading fixes the 100-degree point of the sugar scale in terms of which the purities of other sugars are determined. The 100-degree

point now used by the Bureau for standardization purposes and by the greater portion of the sugar world was determined by European Governments. The Bureau's investigation shows that this constant is too high by over one-tenth of a per cent, a relatively large error. The loss to our Government in duties that should have been collected on imported sugars amounts to over $50,000 a year and the producers of raw sugars have received less compensation than they should have received.

The importance of the issue as brought forward by the Bureau's investigation was recognized by the International Sugar Commission by appointing an international commission with one member from each of three countries—the United States, Germany, and Austria. A member of the Bureau was appointed chairman. Owing to the present conditions abroad, no cooperative work has so far been attempted. The Bureau's investigation has, however, been extended and new values have been obtained for a number of other constants which are dependent on the 100-degree point of the saccharimeter and which are of great importance to the sugar industry, and for scientific purposes. Out of this new work has come additional evidence which strengthens the Bureau's position on the question of the error in the 100-degree point. The necessity for a common basis of testing to be agreed upon by the leading nations is of such importance that the Bureau is still testing all apparatus and the Treasury Department is still collecting the revenue on sugar, on the basis given by the old value of the 100-degree point. It is hoped that a change to the new and correct value can soon be made.

The Specific Rotation of Pure Sugar.

Perhaps the most important of the physical constants of pure sugar (sucrose) is its specific rotation; that is, the rotation of the plane of polarized light by a solution containing unit weight in unit volume. This constant expressed in circular degrees has been studied for many years by the various countries interested. Because of the high purity of the sugar and the precision of measurement required in the research on the constants of the saccharimeter already referred to, advantage was taken of the opportunity to obtain a very accurate determination of the specific rotation. The value secured for sodium light was 66°.529 at 20° C.

The Rotation Dispersion of Sucrose (Cane Sugar).

The amount of the rotation of the plane of polarized light by pure sugar is different for different colors. This variation has not been studied for many years. A more accurate knowledge of these phenomena is required by manufacturers if further advancement in saccharimeter design is to be made. Preliminary measurements have been made and they show a disagreement with the results obtained by previous investigators.

Pure and Intense Light Sources for Polarization Work.

The attempt to measure accurately the rotations of sugar for different wave lengths (colors) of light has necessitated further study of the problem of obtaining pure and intense sources of light. This is perhaps the most troublesome problem in polarimetric work. Never-

theless, considerable progress was made during the year. A burner for either sodium or lithium has been perfected, and improvements made in the rotating cadmium-silver arc. These, together with the quartz mercury vapor lamp, are capable of giving intense light of various wave lengths fairly uniformly distributed throughout the visible spectrum.

In addition some time has been spent on the study of dispersive systems for producing pure light of high intensity with a view to finding more suitable dispersive materials, but this work has suffered on account of the scarcity of optical glasses due to conditions abroad.

Referee Work upon Molasses Testing.

The use of the exhausted molasses from the manufacture of cane sugar for road making, cattle feeding, and distilling purposes is steadily increasing. Only a few years ago this by-product was in many instances thrown into the sea in order to get it out of the way. It is now being shipped to this country in large quantities. The distillers especially are dependent upon it for the preparation of alcohol and alcoholic products by the fermentation of the sugar contained. The molasses is sold on the basis of its total sugar content and to determine this has never ceased being a problem to both buyer and seller. In order to obtain the total sugar, it is necessary to determine not only the sucrose, but also the invert sugar or "glucose" and any other varieties of sugar which may be present. The appraisal of the molasses is based upon the analyses of buyer and seller and a third analyst who acts as a referee. The continued disagreement between the results of the different analysts finally resulted in the Bureau being requested to act in the capacity of referee, and, furthermore, to advise in the selection of suitable analytical methods. It was found that among the methods in vogue are some which although recommended by apparently reliable authorities are seriously at fault. The inherent difficulty of the test as well as the need of selecting the proper methods of procedure will require considerable investigation. This work has progressed satisfactorily and in the meantime the Bureau has made the referee tests on the samples from a number of importations.

The Optical Rotation of Dextrose (Grape Sugar or Glucose).

Dextrose or glucose, sugars of which grape sugar is an example, is a substance widely distributed in nature but is nowhere to be obtained in a pure state. Inasmuch as the analysis of materials containing it depends upon a knowledge of the properties of the pure dextrose, much effort has been spent in purifying the substance and investigating its properties. The investigation of its optical rotation upon the saccharimeter which permits the use of white light sources, and upon the polarimeter, which requires monochromatic sources, has been continued and will be available for publication during the current year. One manufacturing firm has written to the Bureau for information upon this problem. The substance is also available as a standard for controlling the analysis of reducing sugars, a large class of sugars not including sucrose, which are analyzed by their chemical effect upon copper in alkaline solution.

The Optical Rotation of Levulose (Fruit Sugar).

Levulose or "fruit sugar" is of wide occurrence, but, like dextrose, is never found in a pure state. The work of preparation and purification has been continued and a few preliminary measurements made. Inasmuch as the rotation of this substance is particularly susceptible to changes of temperature, apparatus has been constructed to control the latter very precisely during the polarization. This apparatus has also been of use in the work upon molasses, which also demands precise temperature control.

Samples of Standard Sugars.

The work of preparing and issuing standard samples of sucrose and dextrose to be used in the standardization of saccharimeters and for standards of combustion has been continued, owing to the constantly increasing demand by manufacturers and scientists for these materials. A total of 91 standard samples of the sucrose and dextrose were issued during the year. This is an increase of about 50 per cent over the preceding year.

Oven for Vacuum Work.

A high-temperature electric oven has been designed and built for use in the preparation of vacuum apparatus, such as quartz mercury vapor lamps, which it is necessary to raise to a high temperature during the process of evacuation. It is believed that the prolonged heating which is now possible will also eliminate the moisture from the vapor lamps used largely in many kinds of physical investigations.

Magnetic Field of Optical Magnet.

In studying the rotation of the plane of light waves which occurs when many substances are subjected to the presence of a magnetic field, it has been found necessary to know the exact distribution of force in the field produced by the Bureau's large electromagnet.

A preliminary study has been made under various working conditions (different pole pieces, different distances between the pole pieces, different current strengths, etc.). The field of force along the axis of the pole pieces has been explored with a bismuth spiral (a device for measuring the strength of a magnet field), and the intensities plotted against the distance from the center of the field. Curves have also been plotted showing the magnitude of the change in the field strength caused by varying the distance between the pole pieces and also by varying the current strength.

Supervision of the Customs Service Laboratories.

The important work of supervising the Treasury Department's sugar-testing laboratories has been continued. The results obtained by increasing the accuracy of the work have been highly gratifying. A mechanical system for controlling both the humidity and the temperature of the air has been installed in the New York laboratory and a series of comparative sugar tests will be made simultaneously with the Bureau's laboratory. The data secured by these tests should be of great value and it is hoped will settle several vexatious questions regarding the necessity for temperature control in routine sugar testing. Additional assistance has also been rendered the

Treasury Department with the object of making needed improvements in the equipment, personnel, and efficiency of its general customs laboratories.

Polarimetric Tests of Raw Sugars and Molasses.

During the year 1,257 samples of raw sugars were tested. The samples were mainly from the large ports of entry and the results were used to check the accuracy of the customs laboratories. A number of samples of molasses were tested, the nature of the test and the amount of work performed depending on the conditions under which the sample was submitted.

Miscellaneous Polarimetric Testing.

A number of very pure samples of turpentines have been submitted to the Bureau and their natural and magneto-optical rotations determined. It is hoped the data will aid in the identification of turpentines. Other routine tests were made, such as polariscopes, quartz control plates, and cover glasses for polariscope tubes.

Polariscope Tubes for Sugar Testing.

Practically no polariscopic apparatus is manufactured in the United States. In an effort to make a beginning at overcoming this very undesirable condition, the Bureau has designed a polariscope tube. These tubes are used to contain the sugar solution while it is being read in the polariscope. The best European-made tubes are expensive, there is always delay in obtaining them, and they are inadequate in strength and scientific design. After an experimental tube had been perfected at the Bureau, an American firm succeeded in reproducing it so satisfactorily that the number of failures when subjected to testing were less than the foreign-made tubes. The Treasury Department has purchased these tubes in large numbers and they are now on the general market, where they are fast displacing the imported article. There has thus been made available to the American sugar industry a polariscope tube that is superior in design, more durable, more costly to manufacture, and yet less expensive than the European tube. Owing to the present difficulty of securing apparatus from abroad, the sugar industry is suffering from a lack of polariscopic apparatus, with the single exception of polariscope tubes. The Bureau hopes to succeed in establishing the manufacture of all polariscopic apparatus in this country.

Color Standards and Color Specification.

The need of scientifically valid and at the same time practicable methods of specifying the color of materials is urgent in many industries as well as in scientific investigations. The demands made on the Bureau for colorimetric tests and for information and advice relative to color standards and color specification are frequent and persistent and come from sources having such diverse interests as manufacturers, dealers, engineers, psychologists, opthamologists, dairymen, biologists, chemists, and those who for lack of a better term may be called the general public. For example, such requests have been received from the Navy Department, the Weather Bureau, the Bureau of Chemistry, the Pennsylvania Railroad Co., the Automobile Club

of America, the National Dairy Union, the Society of Cotton Products Analysts, the Bellevue Hospital of New York City, the Eugenics Record Office, and various manufacturers, consulting engineers, and scientific investigators. The Bureau's correspondence shows that our correspondents are interested in specifying the color of such substances as glass (signals, headlights, spectacles for eye protection), petroleum oil, cotton-seed oil, turpentine, rosin, paper, textiles (materials for uniforms, silks and felts for organization insignia, etc.), eggshells, egg yolks, butter, oleomargarine, dyes, water (as an index of purity), solutions of various chemicals, portland cement, tobacco, porcelain, flour, blood, and the human skin.

In many cases the need of reliable color specification is due to purely commercial causes. The price of the commodity (cotton-seed oil, for example) is determined by its color and a dispute as to correct grading is a matter of dollars and cents between the buyer and seller. In such cases the need of authoritative standards and methods of measurement is keenly felt by dealers whose interests are involved. On the other hand, there is also pronounced need of color standards and methods of specification in various scientific investigations and researches in physics, chemistry, biology, and psychology, where the interest is often purely scientific and academic. Finally, in still other cases color specification is a matter involving personal and public safety, as in the instance of colored glass for eye protection, railway and marine signal glasses, etc.

In response to many of these varied demands during the year, the Bureau has been able to perform tests and afford information and advice as requested. On the other hand, owing either to lack of assistance or to the undeveloped nature of the subject, it has been impossible to conform to others. It will doubtless be possible to deal satisfactorily with many of these latter cases at some future time, and the applicants have been so informed. In this connection, it may be pointed out that, compared with many other divisions of the Bureau's work, this subject is new and unstandardized, being now in the formative stage. Much of the current work is, therefore, of a preliminary and tentative nature. Assumptions must be tested; fundamental facts must be established by painstaking research; new instruments must be designed and constructed; and methods of measurement must be devised, tested, and systematized. The important thing in this division now is to lay secure foundations for the future, but, as is shown in this report (see below), the current demands of the public are largely met, although not in as complete and satisfactory a manner as is desirable. The demands made on the Bureau for this kind of work would seem to justify the appropriation of a special fund to be used in putting it on a more satisfactory basis.

In the following paragraphs report is made on particular features of the year's work in regard to color specification, color standards, and color grading.

Spectrophotometry.

The fundamental physical basis of color specification is spectrophotometry. Daylight is a mixture of many colored lights of all hues—red, orange, yellow, green, blue, violet, and their transition steps. For the sake of definiteness and accuracy in the subject, a

colored light is specified by its wave length rather than by a color name. A transparent substance which transmits light of certain wave length more freely than others will generally appear colored, the exact hue and tint being determined by the relative transmission for the different wave lengths, while the shade is determined by the total transmission. The task of spectrophotometry in this connection is to determine the transmission (ratio of transmitted light to incident light) for each wave length separately. The instrument for making such determinations is called a spectrophotometer, being a combination of spectrometer (instrument for measuring wave length) and photometer (instrument for measuring light intensity). An accurate specification of spectral transmission (relative transmission for the different wave lengths) constitutes a complete and certain specification of color, as a property of the substance.

During the year progress in spectrophotometry has been made in the following particulars:

Routine experimental methods have been improved and simplified in a way to increase convenience and insure reliability.

By the design of a special slide rule a saving of about 50 per cent in time of computing results has been accomplished with an accompanying increase in convenience and reduction of mental fatigue.

The wave-length scale of the spectrophotometer has been recalibrated by a method independent of that used in its original calibration in 1913, and the first calibration closely verified.

Several satisfactory intercomparisons and countercheck experiments have been carried through in order to test the reliability and accuracy of the methods used.

In order to have at hand a supply of color screens of known properties, the spectral transmission of a number of selected marked glass samples has been determined and the samples and data systematically filed for future reference.

Although a great amount of work remains to be done and is outlined for the future, the spectrophotometric work is now considered to be well established and in good order. During the year reports on spectrophotometric tests or investigations have been made for the Pennsylvania Railroad Co., the Automobile Club of America, Corning Glass Works, Society of Cotton Products Analysts, Florida Cotton Oil Co., National Dairy Union, Bureau of Chemistry, Weather Bureau, and for Mr. Basset Jones, illuminating engineer. Tests were also made for the photometric division of the Bureau of Standards, and the Bureau of Plant Industry was afforded facilities and assistance in a spectrophotometric investigation of certain solutions of interest in the study of chestnut blight. Detailed instructions for calibrating the wave-length scale of the König-Martens spectrophotometer were supplied by request to the United States Food and Drug Laboratory, New York City. Owing to lack of sufficient assistance, it has now become necessary to decline some routine spectrophotometric tests and refer the applicants to private testing laboratories.

Color Specification by Means of the Rotatory Dispersion of Quartz.

The many colored constituents of white light may be separated and recombined in varying proportions by means of a property of

crystalline quartz known as rotatory dispersion. On this principle there is constructed a colorimeter known as the quartz colorimeter. Considerable time has been spent in critical study of this instrument in the attempt to better adapt it to practical use. This work is still in progress. A by-product of this study has been the suggestion of a novel method of comparing the candlepowers of lights of different colors. This proposed method was definitely outlined by a member of the Bureau staff at the meeting of the American Physical Society in April, 1915.

Color of Cotton-Seed Oil.

The investigation of the color of cotton-seed oil mentioned in previous reports has been continued, although it has been greatly handicapped for lack of assistance. Progress has been made in the following particulars:

The spectral transmission (see paragraph on "Spectrophotometry") of a number of authentic samples of oil has been determined.

The relative transmission for blue and yellow has been determined (by means of a photometer and selected color glasses) for a number of samples and the results considered as a function of color graded by other methods. The determination of this relative transmission may prove to be a satisfactory and practicable means of grading the oil.

The permanency of the color under different conditions has been studied. It is commonly known that the color is very fugitive when exposed to light and air and that it fades more slowly in the dark. Experiments this year have shown that the color is very permanent even when exposed to direct sunlight, provided all air has been removed and the oil is kept sealed in vacuo. The establishment of this fact is important as indicating the possibility of preserving standard samples.

The color of samples of oil in different thicknesses has been read on the Aron's chromoscope (a type of quartz colorimeter) to show the relation between thickness and the scale readings of this instrument.

By invitation, the Bureau's expert in charge of this investigation made a report on it at the Annual Convention of the Society of Cotton Products Analysts, Birmingham, Ala., in May, 1915, and this report is being published in the Proceedings of that society.

Desiring to expedite this investigation and have it prosecuted more rapidly than the Bureau's resources would permit, the Society of Cotton Products Analysts and the Interstate Cotton Seed Crushers' Association have provided about $1,700 to pay salaries of assistants to carry on this investigation under the direction of this Bureau. Accordingly, at the close of the year plans were adopted for the conduct of such an investigation in the Bureau's laboratories. An assistant was selected and the work under this arrangement is now well under way.

Method of Specifying a Color Limit for Oleomargarine.

At the request of the National Dairy Union, the Bureau has devised a method for specifying a color limit for oleomargarine. The inception of this method was mentioned in last year's report. During the past year it has been developed and perfected and more thoroughly tried out. This form of specification is believed to be practicable as well as scientifically valid. The essential feature of

the method is the specification of the color limit in terms of the relative reflecting power for blue and yellow. For the sake of definiteness and precision, the wave lengths of the blue and yellow are specified. The specification then reads: The *diffuse reflecting power for light of wave length 436 micromillimeters (blue) shall not be less than — per cent of the diffuse reflecting power for light of wave length 578 micromillimeters (yellow), the temperature of the sample being 70° F.* The Bureau has designed and constructed a suitable apparatus for measuring the ratio herein specified. This form of specification was recommended to the National Dairy Union at its conference at the Bureau June 2, 1915; and that organization has adopted it, inserting "70" in the blank space before "per cent."

Investigation of Proposed Rosin Color Standards.

As mentioned in the report for 1914, a comparison of the colors of natural rosins with their proposed glass standards for rosin colors had been undertaken at the request of the Bureau of Chemistry, Department of Agriculture, and was in progress at the close of the fiscal year 1914. Final report on this investigation was made to the Bureau of Chemistry on November 27, 1914. It summarized the following conclusions:

1. The proposed glass standards do not match the same nominal rosin grades (present trade standards) submitted. Some, indeed, more nearly match other grades. The proposed standards are generally (with one or two exceptions) paler than the present rosin trade standards submitted.
2. The relative transmission for light of different colors is not the same for the proposed standards as for the natural rosin. This is an undesirable characteristic.
3. The color intervals between successive grades of the proposed standards are not of uniform value.

Establishment of a Standard Method for Testing the Transparency of Tracing Cloth.

The necessity of measuring in some way the transparency of tracing cloth and semitransparent papers has been brought to the Bureau's attention by the request of the Treasury Department, Navy Department, Post Office Department, and several manufacturers and dealers. In order to bring about uniformity and a general understanding among all interested parties, it has been necessary to formulate a standard method of test. The Bureau's method which has been used in a tentative way for two or three years previously has now been perfected and definitely adopted as a standard routine test method. A circular statement was issued in February, 1915, and sent to interested parties; and the method as outlined therein has been approved by several qualified experts outside of the Bureau. The Navy Department, which formerly had a specification of its own, has signified its intention of writing future specifications in terms of this method of test.

The essential feature of the method is the measurement of the contrast between perfect black and perfect white as seen through the tracing cloth. The Bureau has designed and constructed suitable apparatus for making this measurement.

The American Ceramic Society has also become interested in this method as affording a means of measuring the translucency of porcelain. By invitation the Bureau's expert on this subject described the method to that society at its annual convention at Detroit in February, 1915, and his paper is being published in the Transactions of that society.

Study of Method of Measuring the Turbidity of Spinal Fluids.

At the request of the Psychiatric Institute of the State Hospitals of New York, a study of the turbidimeter was made to determine its usefulness in measuring the turbidity of spinal fluids. The study of this serum is of importance in the diagnosis of diseases of the brain. The results obtained with the preliminary instrument show that it is entirely applicable, and a representative of the Bureau has assisted the institute in designing apparatus to be used in this work.

Study of the Properties of Fog at Sea.

The great influence of fog upon the safety of vessels at sea makes a scientific investigation of fog desirable.

A preliminary investigation of the properties of fog at sea was made in cooperation with the ice patrol of the Coast Guard Service on the May cruise of the *Seneca*. A study was made of the number of nuclei present in the sea atmosphere. Nuclei are small "dust particles," always present in the air, upon which the water vapor condenses. The number of these condensation nuclei, or the nucleation, is a most important characteristic of the atmosphere in relation to fog. The amount of liquid in the fog particles was also studied.

Information Furnished on Optical Subjects.

Information relative to such subjects as color specification, transparency, translucency, turbidity, and interferometry (methods of measurement in terms of the wave length of light) has been supplied on request to many applicants, sometimes by correspondence and again by personal conference. Among those served in this way were the Navy Department, the Department of Agriculture, the Pennsylvania Railroad Co., the General Electric Co., the Waltham Watch Co., the A. D. Little Co., of Boston, Bellevue Hospital, of New York City, and others.

Investigation of the Commonly Found Errors in Photographic Lenses.

Methods have been developed for the measurement of the errors which interfere with good definition near the center of the field of view. Measurements have been made on the principal types of commercial lenses for four different colors and for zones extending from the center to the edge of the lens.

This investigation in conjunction with previous ones gives a numerical measurement of the quality of a lens. The results of this investigation are being prepared for publication.

Speeds of Photographic Shutters.

Preliminary determinations of the speeds of photographic shutters have shown that many shutters are erroneously marked and, there-

fore, an investigation of their speeds and efficiencies has been started. As an example, several shutters gave an almost uniform speed of 1/40^{s} when set at 1/25^{s}, 1/50^{s} and 1/100^{s}.

Standard Lenses for Opticians' Trial Sets.

An investigation of the methods of standardization of opticians' trial sets is being carried out in order to eliminate some of the endless confusion arising from the numerous errors in trial set standards. Two sets submitted by one of the leading manufacturers are now being standardized and will be used by them as primary standards.

Testing Optical Systems.

The testing of optical systems has been done largely for the different departments of the Government. These tests embrace various types of optical instruments, including photographic lenses, searchlight mirrors, binoculars, telescopes, projection lenses, submarine periscopes, and gun sights.

A marked increase in light transmission of certain optical instruments has been noted since last year. In some cases this increase is more than 40 per cent.

Refractive Indices.

The extent to which light is deviated from a direct course when passing through a transparent substance is defined as the refractive index of the substance.

Refractive index determinations have been made of glass and various materials as requested for tests. Also some standard test plates have been furnished to manufacturers for calibration of their instruments for measuring refractive indices.

Information Furnished as to Optical Instruments.

Many requests have been received for information and advice concerning optical instruments.

A comparative investigation of the optical parts of motion-picture machines was made for the purpose of selecting the most suitable machine from those submitted as samples in connection with the purchase of such machines by one of the departments.

Many have applied for advice regarding the practicability of projected optical systems, and much assistance has been rendered in this direction. Simple formulæ for spectacle lenses free from astigmatism for oblique rays were developed, at the request of one optical firm.

Considerable time has been devoted to consultation work with the various departments of the Government, as well as with the different divisions of this Bureau with reference to the design, specification, testing, and use of optical systems. Also, data have been furnished which enabled some optical systems to be repaired in this country where formerly repair parts could only be obtained abroad.

Radiometry.

In many physical, chemical, and physiological investigations it is of great importance to know the behavior of substances when subjected to stimuli of radiant power, light, and heat rays; that is, radiant energy of all wave lengths, whether visible or invisible to

the eye. During the past year the Bureau has continued its investigation in connection with the improvement of instruments for measuring radiant energy, especially instruments for measuring radiant energy in absolute value. Important advances were made in shielding the galvanometer from external magnetic disturbances and thereby improving the reliability of the radiometric measurements.

The design of galvanometer coils was also investigated. Coils wound in 1, 2, or 3 sections of graded wire were compared with a set of three standard coils, and the magnetic force exerted by them was thus determined. As a result of this investigation, a coil, wound empirically with a single grade of wire, was found which is as efficient as a coil wound according to theory and having three sections of graded wire. Furthermore, a coil which was empirically wound was found which was about 20 per cent more efficient than a coil having the same resistance but wound according to theory. In addition to magnetic shielding and the design of the coils, further attempts in improving the galvanometer are in progress. The results of this investigation are ready for publication.

Nocturnal Radiation Measurements.

Nocturnal radiation is usually a loss of heat from terrestrial substances into space. This has a profound influence upon terrestrial temperatures and, hence, upon vegetation. During the past year instruments were constructed for the United States Weather Bureau for investigating this loss of radiation into space, the direct practical application being the question of the cause of frosts upon certain mountain sides which are covered with fruit trees.

Radiometric Outfit for Physiological Work.

Radiometric instruments, including galvanometer, thermopile, etc., are in the process of construction for the United States Public Health Service. This apparatus is to be used in measuring light stimuli in connection with investigations of vocational diseases.

Glasses Which are Opaque to Infra-Red Rays.

There has been considerable agitation of the question of the protection of the eyes of workmen exposed to the intense infra-red radiations from red-hot furnaces and from the intense luminous radiations from arc lamps, etc. Glass manufacturers are actively engaged in the production of spectacle glasses which absorb all the infra-red rays, but have a high transmission in the visible spectrum. During the past six years and especially during the past year various glasses have been examined for their transparency in the infra-red, and from the results obtained the Bureau is in a position to give authoritative information relative to general cases of eye protection by means of colored glasses.

In this connection, it is relevant to repeat the statement made in last year's report regarding the necessity of carrying on investigations of the properties of materials, even though the immediate practical application of the data may not be apparent. In that report cases were cited where the data obtained did not appear to have immediate application. The present case of the application of data, obtained some years ago, on the transmission of colored glasses is a

further illustration of the importance of carrying on investigations of the properties of materials, even though an immediate application can not be made of the data so obtained.

The Stefan-Boltzmann Constant.

The coefficient of total radiation from a perfectly radiating body, commonly called the Stefan-Boltzmann constant, was thoroughly investigated during the past year by means of an improved radiometer applicable for evaluating radiant energy in absolute measure. The investigation was made under various conditions as to atmospheric humidity, blackness of the radiator, different kinds of receivers, etc. The value of the coefficient of total radiation as determined by this method is $\sigma=5.74\times10^{-12}$ watt cm^{-2} deg^{-4}. The investigations made during the past twenty years, using different methods, were subjected to rigorous analysis. Corrections were made for atmospheric absorption, and it was then found that all the reliable investigations give values which are close to $\sigma=5.7$. The data obtained in this investigation have been assembled into a paper which is ready for publication. The first part of this paper deals with instruments for evaluating radiant power in absolute measure; the second part of the paper gives an analysis of all the data available on the coefficient of total radiation, as well as subsidiary data on atmospheric absorption, etc.

Measurements on the Radiation from Stars.

During the past 47 years numerous attempts have been made to measure the heat received from stars. In last year's report attention was called to the perfection of a minute thermocouple of bismuth-platinum in a vacuum maintained by means of metallic calcium. During the past year a number of these stellar thermocouples were compared in the laboratory and also in connection with a 3-foot reflecting telescope at the Lick Observatory, Mount Hamilton, Cal. The instruments proved to be satisfactory. Measurements were made on 112 celestial objects, including 105 stars, the bright and dark bands of Jupiter, the rings of Saturn, etc. Stars to the 6.7 magnitude were measured, and the whole research constitutes the first really successful measurement of stellar radiation by means of instruments of this type. The data obtained have already found useful application and it is hoped that further work may be continued. With this end in view, the above mentioned investigation of the efficiency of galvanometer coils was made; further work is in progress on increasing the sensitivity of the galvanometer and the thermocouples. Recently two papers have been published by astronomers who used the above mentioned radiometric measurements in discussing the probable temperature of stars.

5. CHEMISTRY.

Standard Analyzed Samples.

The demand for the standard samples that are under the control of the chemistry division has shown a good increase of almost 200 over the previous year. A part of this increase arises from the

abnormal demands of the last four months on the part of certain industries, growing out of the European war.

The worth of the Bureau's series of analyzed standard samples, and the need of standards of analysis of the highest purity to those engaged in industrial pursuits, as well as to those engaged in teaching and studying, is so well established that the maintenance and increase of this series of (at present) 38 samples should be assured by a moderate fund continued from year to year. 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 standard samples.

No new samples have been added to the existing series, but the Alabama iron, referred to in the last report as iron E, has been subjected to analysis and will be issued to the public as soon as certain discrepancies are reconciled. An interesting development of the analysis of this iron is the discovery that it has an unusually high vanadium content of about 0.08 per cent. The inquiry at once suggested itself: Is this normal or accidental? If normal, it would mean that the Alabama ore, coke, or flux used in making this particular iron were, one or more, appreciably vanadiferous. Tests instituted by the chief chemist of the Tennessee Coal & Iron Co., at the suggestion of the Bureau, show as far as they go that the Alabama ores and coke, but not the limestone flux, do carry vanadium, but in amounts less than is shown by the pig iron E. The matter has undoubtedly some commercial significance and should be investigated further by those interested.

It has not been possible as yet to devise a method by which a cast brass can be produced of composition so uniform throughout the ingot as to obviate the need of mixing after the mass has been reduced to chips. The method of "atomizing" a pot of molten metal by means of superheated steam seems well adapted for relatively low melting alloys, like type metal and babbitts, but has not been successfully applied yet to brasses. Even with the white alloys, the yield of grains of suitable size is rather low (30 to 40 per cent), so that an inconveniently large mass must be melted in one lot in order to provide the needed few hundred pounds of finished product. In cooperation with the Bureau, experiments will be continued by representatives of the National Lead Co. and the New Jersey Zinc Co. in the hope that the process can be improved and made applicable to the higher melting alloys.

Chemical Tests of an Umpire Nature.

The Bureau is frequently requested to determine for commercial firms, or to help them to determine, the composition of a material which they wish to employ as an analytical standard in their own work or concerning the composition of which there is seemingly irreconcilable dispute. Such requests usually involve more or less research and are refused unless it is shown that their own or commercial analysts are unable to afford the information sought. If shown, however, it is held to be eminently proper to give all the aid possible.

Some recent tests of this nature have been on the manganese content of a certain steel standard; the silicon content of certain steels;

the sulphur content of certain irons; the lead content of a western standard lead ore; and the correct determination of cadmium in spelter.

Usually the work done at the Bureau has been accepted as conclusive by those interested, either as to the true composition or as to the method used. The reputation of the Bureau as a court of resort in many lines of chemical analysis is high, and it should be maintained by increasing the number of men assignable to analytical research of a high order and adequately recognizing the ability of those who prove themselves most worthy.

Investigation of the Methods Relating to the Analysis of Irons and Steels.

The large amount of iron and steel testing called for and the large number of new methods of analysis, or modifications of old methods that are put forth, make it imperative to devote perhaps more time to trying out certain of these methods than is the case in any other branch of the Bureau's analytical work. Such work may lead to modifications of the methods employed by the Bureau, but as a rule the knowledge acquired from it, while of value, is not of a kind to justify publication. Examples of this kind that have been handled are, precipitation of tungsten as the pentoxide by stannous chloride; the influence of vanadium on the titration of iron by potassium dichromate; the titration of titanium solutions by ferric chloride; the titration of ferric chloride by sodium thiosulphate; the reduction of compounds of chromium, vanadium, molybdenum, and tungsten in the zinc reductor, and, the titration of iron by stannous chloride. A new method of determining vanadium and chromium in the presence of each other is now being studied.

Preparation of Iron Carbon Alloys.

The preparation of pure electrolytic iron and of alloys of iron and carbon begun in the previous year has been actively continued in cooperation with the Division of Metallurgy. A paper embodying the results of this research is nearly ready. The technique necessary for such investigations, involving the selection of suitable furnaces, crucibles, electrolytic baths, and related questions, has been worked out for this and similar future investigations. A series of alloys with not to exceed 0.02 per cent of total impurities has been made for use in exploring the thermal equilibrium diagram for the iron-carbon system. Preparation of large ingots by similar methods for investigating other physical properties is under way.

High-Temperature Carbon Combustions.

The experimental work on high-temperature carbon combustions, referred to in the last report, has been completed and the results are being prepared for publication. Suitable high-temperature apparatus has been devised for making combustions at a temperature above the melting point of iron oxide, so that carbon retained by the oxide may be liberated. The method has been applied to a wide range of the Bureau's standard irons and steel samples, with the result that the certificate values are in most cases confirmed, the maximum deviation by the new method being 0.02 per cent carbon (higher) in one or two instances.

Test of Surface Combustion Furnace.

Much work has been done on a furnace for high combustion and a paper on the subject is about ready for publication. The work shows that temperatures in excess of 1700° C. can be obtained readily with gas of not over 620 B. t. u. heating power; that the best ratio of air to gas is in the neighborhood of 5.5 to 1, and that small deviations from this ratio exert marked effects on the maximum temperature attained. Further work with refractories that will permit of attaining higher temperatures is contemplated.

Ladle Test Ingot Investigation.

The first stage of the ladle test ingot investigation is completed and has been reported upon to the American Society for Testing Materials. The conclusion reached is that no geometrical shape of test piece can be chosen to give a sound ingot unless the steel has had previous suitable metallurgical treatment to eliminate the harmful effect of occluded or dissolved gases, oxides, and slags. The next stage of the work will be an endeavor to find a simple and proper treatment to insure sound ingots.

Standard Methods for the Analysis of Pig Iron and Iron Castings for Export.

The chief chemist of the Bureau, as the American representative on a subcommittee of the International Society for Testing Materials, has prepared, with the assistance of other experts, proposed methods for the analysis of pig iron and iron castings for export, which will appear in this year's Year Book of the American Society for Testing Materials as tentative methods for use in this country, subject to final action by the society a year hence.

Standard Methods for the Analysis of Steels.

In cooperation with the American Society for Testing Materials, the Bureau has taken a leading part in compiling methods for the analysis of plain and alloy steels. The first of these specifications has received the approval of the society and the second is before the society for further action.

Tests on Steel for Other Divisions of the Bureau.

Many analytical tests of a more or less extended nature have been made in cooperation with other divisions of the Bureau, among which may be specially mentioned those on rail failures.

Sampling and Analysis of Coal.

In cooperation with the committee on coal analysis of the American Chemical Society, acting in conjunction with a similar committee of the American Society for Testing Materials, the Bureau has helped in the revision of methods for the sampling and analysis of coal. These methods are now before the latter society for a year's consideration before the final vote is taken.

Chemical Work in Connection with Paper.

The first of the work on paper pulp is nearing completion. The chemical constants of the more important pulps have been deter-

mined, and the resistance of the pulps to hydrolizing and oxidizing agents has been ascertained. The effect of esterification has been studied. The observations made will assist in a later study of the effect of filling and sizing agents upon the life of paper.

The study of changes occurring in ground wood pulp under the influence of active oxygen, sunlight, and heat has been completed. This is of importance in determining the effect of residues of lignin in paper pulps.

Some information has been gained on the determination of sizing agents.

Textiles.

The chemical division has made numerous determinations of moisture in fabrics for the textile section of the Bureau in an effort to substitute a bone-dry basis for the air conditioning of textiles. A large amount of routine examination of fabrics has also been conducted for the textile section.

Distinguishing Sisal and Manila.

An attempt has been made to find some means by the use of stains of distinguishing manila from sisal in cordages, but with only partial success, since such distinctions as have been noted are not applicable to both coarse and fine varieties. The situation has been put before manufacturers of cordage in the hope that some of them may be able to follow up the clues indicated by the Bureau.

Lubricating and Transformer Oils.

Considerable time has been spent in endeavoring to improve the "carbonization" test and to connect the carbonization factor with the behavior of oils under other conditions. The results of this investigation are now being prepared for publication. The test, similar to that of Kissling, seems to give satisfaction with gas-engine oils. A leading oil refinery used part of one of the Bureau's reports as an advertisement and quite recently the Bureau was informed that the oil purchased on its recommendation by the Post Office Department is entirely satisfactory.

Data on the carbonization of other classes of oils are being accumulated.

Gum Arabic.

A research begun in the early days of the Bureau's chemical activities on methods for detecting and determining gum arabic has been renewed. A new method was devised, but has been withheld until more information can be gathered as to one or two points. This work was taken up in connection with Government purchases.

Articles Involving Danger to Life or Property.

Many reports and opinions covering the chemical composition of a wide range of substances supposed to involve fire or life risk have been prepared for the Steamboat-Inspection Service to serve as a basis for its decisions regarding the acceptance of the articles in question as freight by passenger-carrying vessels. In most cases no laboratory work was necessary; in others, simple tests sufficed, while

the still pending question of ferrosilicon may eventually lead to an experimental research.

Some of the more important subjects upon which the Bureau has been requested to report with reference to safety are ferrosilicon, porosity of fillers used in acetylene cylinders, thermit, polishing cloth, and slickers.

Chemical Analysis of Rubber.

Considerable progress has been made in studying methods of chemical analysis for rubber goods. A paper on the determination of total sulphur in rubber is in print and another on the determination of barium sulphate and carbonate is nearly completed. Since many specifications permit the use of barium sulphate as a mineral filler without having the sulphur which it contains considered as part of the total sulphur, it is necessary to be able to determine this constituent in the presence of any possible disturbing factor.

Cooperative work on rubber has been continued with two organizations, namely, the American Chemical Society and the Joint Rubber Insulation Committee. In cooperation with the latter body, the Bureau has devoted much effort to the development of a more satisfactory method for the determination of fillers in rubber.

The rubber experimental mill at the Bureau has been in successful operation and has proved of much assistance in connection with the above investigation. Its use has revealed the fact that the Bureau's method for determining the amount of oil substitutes present in rubber compounds yields low results.

A tubing machine and a steam vulcanizer have been added to the existing equipment and with these the subject of rubber laboratory tubing will be investigated. The Bureau has taken up this subject of tubing with several manufacturers and as a result three new compounds are now being tried out in actual service. It is hoped that these compounds will be more satisfactory than those that have been obtainable from the schedule of the General Supply Committee.

A third edition of Circular No. 38, on the Testing of Rubber Goods, has been issued, very much enlarged by the addition of new matter, including the chemical methods in use at the Bureau.

Printing Ink.

Circular No. 53, on The Composition, Properties, and Testing of Printing Inks, has been issued and is in frequent demand. Additional information is being gathered for the purpose of extending the scope of this circular. Very little has been published heretofore on the subject.

Determination of Oil and Resin in Varnish.

The Bureau has been studying the question of the determination of oil and resin in varnish and the results obtained show a decided advance in this difficult subject. A paper dealing with this investigation is now in course of preparation.

Soap.

Practically all branches of the Government service have been invited to cooperate with the chemistry division of the Bureau in pre-

paring specifications for soap materials, with the view of reducing the number of varieties now bought and of making it easier for manufacturers to bid in connection with the annual contracts. There has been prepared the first draft of a circular of information on soap, which is now in the hands of representatives of the various branches of the Government service and numerous manufacturers for criticism.

Paint Investigation.

The question of specifications for materials used in paints and varnishes has always occupied a considerable share of the attention of the chemical division. The preparation of specifications for paint materials is an important field of work and much thought has been devoted to this subject in cooperation with the American Society for Testing Materials. Other subjects handled during the past year in cooperation with the same society have been the revision of specifications for purity of raw linseed oil from North American seed, new specifications for the purity of boiled linseed oil from North American seed, the purity of raw Chinese wood oil, turpentine, and the definition of terms used in paint specifications. It is believed that this work will be of material assistance to the paint and varnish industries, as well as to the users of these materials. The Bureau has also cooperated in preparing methods for the analysis of white pigments, which are now being considered for adoption by the American Society for Testing Materials. These methods of analysis were developed almost entirely in this Bureau and a large amount of work incident to the preparation of the specifications and definitions was done by the chemistry division.

Considerable work has been done during the past year in connection with an exposure test of certain commercial white paints on wood. This investigation is still in progress.

Gas Analysis.

In furtherance of the Bureau's efforts to improve and standardize methods of gas testing, a comprehensive investigation of the lead-acetate test for hydrogen sulphide in gas was carried out and the results have been published as Technologic Paper No. 41. The numerous factors which affect the delicacy and reproducibility of this test, which is of importance in testing the purity of satisfactory gas supplies, have been investigated and a standard procedure and apparatus for carrying out the test have been recommended. It is of interest to note that the American Gas Institute has adopted practically the recommendation of the technologic paper for the gas analyst's handbook, which is in preparation.

An exhaustive study of methods and apparatus for exact and commercial gas analysis has been begun. Several new forms of apparatus for gas analysis and for use in closely related problems have been devised and are now under construction, including notably a weight burette with very accurate compensator for temperature changes and a balance for determining the specific gravity of small amounts of gas. A very complete bibliography of the literature on gas analysis has been prepared. This bibliography, which contains more than 2,000 references, is arranged in duplicate by subject and by author and includes many abstracts of the articles.

Preparation and Testing of Gases of High Purity.

The Bureau has been engaged for some time in the preparation of apparatus and the devising of means for making in a high state of purity the various gases which are the constituents of commercial gas supplies. The preparation of these gases and the determination of their physical and chemical properties will form an important part of the laboratory investigation for a considerable time to come, being preliminary to the determination of the properties of their mixtures with each other as they occur in fuel and illuminating gases.

Hydrogen has been prepared by electrolysis and by the action of sulphuric acid on zinc and of hydrone on water. A generator working on the Kipp principle, but possessing a number of novel features, has been designed and constructed for use in generating hydrogen from zinc and acid. This generator can be evacuated completely before filling with acid and air-free acid can be introduced without danger of contamination. The space above the liquid in the reservoir is at all times filled with hydrogen of the highest purity, thus preventing the contamination by air of the hydrogen generated. A very satisfactory electrolytic generator and gas-purifying train has been constructed. Several samples of the hydrogen from the different sources mentioned have been tested by chemical analysis, by determining the density of the gas by weighing, and by intercomparison in the gas interferometer. The application of the interferometer in gas analysis problems is being studied, particularly as offering a valuable means for the accurate testing of the pure gases that are to be prepared.

Te determination of the heat of combustion of hydrogen has been undertaken by the chemical division in cooperation with the division on heat and thermometry. Satisfactory progress has been made on the preliminary series with this gas and it is planned to continue the work, both with the hydrogen and with the other pure gases as they are prepared. The methods developed on the pure gases can then be applied on synthetic mixtures of known composition. The calculation of the heating value of gas mixtures from results of analysis is very desirable, but until much progress shall have been made in the study of gas analysis, as well as in the study of calorimetric constants, there is little hope of making application of this method of computation for accurate work.

A number of pieces of apparatus worthy of mention have been designed for use in the laboratory work in connection with gas investigations. There has been designed, and constructed in the instrument shop of the Bureau, a gas holder of 14 liters capacity which is well adapted to storing gases of high purity without contamination, since the gas is retained in contact only with glass, steel, and mercury. Other pieces of apparatus that have been devised are an apparatus for the determination of sulphur in gas, possessing a marked advantage over that previously used; several new forms of gas-washing apparatus, which have been found very convenient in gas analytical work; and a new form of pipette for gas analysis work, intended to give rapid and complete absorption. A thermostat has also been built which will be used first in connection with the determination of gas density and later for general work in the laboratory. This apparatus operates very satisfactorily, the stirring and

regulating devices being so efficient that the temperature is maintained constant within 0.005° C.

Control of Purity of the Bureau's Oxygen Supply.

The oxygen supply of the Bureau has been examined for possible impurities a number of times and tests have been made on it to determine the amount of combustible impurities which would vitiate the results obtained in exact calorimetry in which this oxygen has been used.

Colorimetric Determination of Acetylene.

Considerable attention has been given during the past year to an investigation of the colorimetric method for the determination of acetylene, suggested by work done in the previous year. An account of the earliest work on this general problem was published in December, 1914, in the Journal of the American Chemical Society as "A quantitative test for water by the use of the acetylene-cuprous chloride reaction." The quantitative application of the method for the determination of acetylene proved to be very satisfactory, as results indicate a possible accuracy of about 0.02 mg. C_2H_2, but the effort which was made to apply the method to the quantitative determination of very small amounts of water brought to light two difficulties which seemed insurmountable, namely, (1) the difficulty of removal of acetylene from the calcium carbide which was used, and (2) the incompleteness of the evolution of acetylene from the water in the samples taken. A paper embodying the results of this research is nearly ready for publication.

Determination of Phosphorus and Sulphur in Calcium Carbide.

A new method for the determination of phosphorus and sulphur in calcium carbide has been developed, but the results of the investigation have not yet been prepared for publication.

Distillation of Liquid Air in a Magnetic Field.

A brief article was prepared and published in the Journal of the American Chemical Society on experiments made two years ago on the distillation of liquid air in a magnetic field. The object of the research was to ascertain if distillation in the magnetic field would have a favorable effect on the separation of the constituents of the air; apparently some advantage does accrue, but not a great one.

Preparation of Naphthalene.

A new lot of naphthalene was prepared by the chemistry division for use as a standard material for the calibration of calorimeters. Fifty pounds of crude material was purified by crystallization with subsequent sublimation in vacuo.

Bituminous Materials.

A careful study has been made of the equipment and methods for testing bituminous materials in the laboratories of manufacturers, consumers, public institutions, and others, and as a result the equipment of the laboratory of the Bureau dealing with these materials has been brought more up to date and important modifications have

been made in the methods in use for routine testing. In connection with bituminous paints, it has been found that the asphalt used is fluxed not only with the common fluxes, asphaltum or paraffin oils, but also with rosin, pine oil, stearine pitch, fats, and fatty acids.

Phosphate Rock Analysis.

Very little, if any, progress has been made on the problems relating to the analysis of phosphate rock. It is very desirable that this work be carried to completion in order to render available the large amount of data that has already been obtained on this subject.

The Chemistry of Electrotyping.

The study begun over a year ago to give electrotypers much needed information for the control of their solutions has been prosecuted actively, mainly by analyzing a large number of samples received from commercial electrotyping plants. The primary object of these analyses was to gain a knowledge of the conditions now prevailing in the industry and of the problems in need of study.

In addition an effort has been made to get into closer touch with electrotypers' organizations, both of employers and employees, by means of informal interviews, wherein the nature and advantages of scientific work in this field are pointed out. In general these bodies have shown a marked interest in such work. A brief circular (Circular No. 52), giving simple methods of analysis of copper electrotyping solutions, has been issued. A revision of this circular is now in preparation which will contain a summary of the information that is available in this field and an explanation of the simple electrical and chemical terms.

In cooperation with representatives of the electrotyping industry and with certain other divisions of the Bureau, the chemistry division has undertaken the following researches in connection with this subject: The determination of the density of copper sulphate-sulphuric acid solutions; the determination of the conductivity of copper sulphate-sulphuric acid solutions; a study of the effect of the conditions of deposition upon the hardness, tensile strength, and structure of electrolytically deposited copper; and the possibility of the application of cobalt deposition to electrotyping.

Other problems in urgent need of study for the benefit of the electrotyper's industry are the composition and physical properties of ozocerite and other materials used in molding wax, the composition and physical properties of graphites suitable for electrotyping, and the operation of nickel electrotyping baths. The latter might well be included in a study of nickel-plating baths in general.

Investigations Relating to Electroplating.

The advance thus far made toward the study of electroplating has been of interest primarily to electrotypers. The American Electroplaters' Society recently requested the Bureau to cooperate with them in a study of plating operations. Such a study would involve problems in electrochemistry, analytical chemistry, and metallography. It is impossible, however, for the present limited force to make rapid progress in the electrotyping field, let alone that of

electroplating. It is recommended, therefore, that a special fund be secured, if possible, to be devoted to the study of electrotyping and electroplating problems.

Standard Cells.

Progress on the investigations having to do with standards of electromotive force has not been on the whole as satisfactory as could be desired, because of frequent interruptions made necessary by other work. A few cells have been set up with mercurous sulphate made by the alternating current, which gives very constant and reproducible results. Twenty kilograms of cadmium sulphate have been purified and this material will be used in setting up the large series of cells necessary to test the alternating current product. Some 20 additional samples of mercurous sulphate have been made under conditions where each of the factors have been varied for the purpose of determining the best conditions of preparation, although it is already fairly well known just what constitutes satisfactory conditions. This preparative work, which can be almost indefinitely extended, has been temporarily abandoned and the setting up of cells with material made under conditions that are satisfactory will give results in the immediate future. Unsaturated cells have been set up for the first time for the use of the Bureau's laboratories, and they show excellent behavior.

Chemical Work in Connection with Refrigeration Constants.

Progress in work on the constants of materials used in refrigeration has been satisfactory. The purification of materials is well in hand and has been keeping pace with the requirements of those interests using them for physical measurements.

The subject of ammonia has been occupying a considerable share of the attention of the chemistry division. An apparatus with many new features has been devised for the fractional distillation and, possibly, the sublimation of substances at low temperatures. In cooperation with the optical division, the use of the characteristic absorption bands of pyridine in the ultra-violet has been tested, using aqua-ammonia. The indications are that this test is sensitive to 3 parts in 1,000,000. Further work is necessary and, if possible, a similar method will be applied for the detection of acetonitrile in ammonia. Carbon compounds as such are being tested for by combustion of the gaseous ammonia in oxygen and estimation of the carbon dioxide formed.

While it has been possible to pick out the best commercial ammonia as a starting point for preparative work, and perhaps for general chemical work where gaseous ammonia may be used, it will be necessary to do some additional work before rational specifications for the material can be developed. Results obtained from the investigation being conducted on gas formation will have a considerable bearing on these specifications.

The cause of formation of noncondensing gases has been attacked from all the various points that have suggested themselves, which makes the work rather extensive in scope. Work on the following more or less independent phases of the problem is under way and

some progress has been made on each: The solubility of gases in liquid ammonia; decomposition of ammonia under working conditions of both the absorption and compression plants, which are to be simulated in an apparatus for that purpose; gas formation under working conditions in the plant of the Bureau with special reference to the locality of formation and behavior of the gas in the system; and a study of the quantity of the gas formed and the amount of ammonia lost in purging in the commercial plants of Washington and Baltimore.

Sodium chloride has been purified for use in making brines for the density and specific heat determinations. Calcium and magnesium chlorides that are to be used for similar purposes have been analyzed.

Conductivity of Electrolytic Standards.

Some progress has been made on the investigation of the absolute measurement of electrolytic resistance. It is desirable that more attention be given to this important problem, since the need for research on this subject is becoming more and more evident.

Platinum Investigation.

It is not necessary to renew in its entirety the suggestion of last year for the transfer of the Mint's platinum to the Bureau of Standards, since the Director of the Mint has undertaken, as soon as arrangements can be made, to provide Government laboratories with platinum utensils derived from the platinum which accumulates during refining operations in the Mint. There will be needed, however, an advanced analyst to make a specialty of the analytical chemistry of the platinum metals, for upon such work will depend in large measure the value of the advice this Bureau can give to the Mint in reference to the proper specifications for different forms of finished ware. The services of a very competent chemist will be needed for some years, working in cooperation with certain other divisions of the Bureau, on the determination of the constants of the metals of the platinum group and of their alloys.

Research of the Methods and Standards Employed in Volumetric Analysis.

A study of the methods and standards employed in volumetric analysis is of fundamental importance for exact work in almost all lines of chemical analysis. The need for this research is even more pressing than a year ago, and work should be undertaken on this important problem as soon as possible. The services of a chemist qualified in physical and analytical chemistry will first be needed and with the advancement of the work additional help will become necessary.

Chemical Testing.

The routine testing in the chemical division during the past year has increased very largely in consequence of taking over the work of the contracts laboratory of the Bureau of Chemistry. However, the increase is not altogether due to this cause, since there has also been a noticeable increase due to improved methods in the purchasing of Government supplies.

More than 12,500 tests of materials were made by the chemical division during the year. They involved the following materials: Ferrous metals (irons and steels), 981; coated metals, 641; nonferrous metals and alloys, 1,106; material from electrotyping baths, 398; cement materials, 1,296; coal tars and asphalts, 533; saturated felts, 258; burlap and building paper, 211; linseed oil and turpentine, 541; driers, 313; varnish and shellac, 610; red lead, 184; white lead, 284; putty, 186; graphite paint, 249; miscellaneous paint colors, 472; greases, 51; soaps, nondrying oils, and metal polishes, 498; oils (lubricating), 373; inks (printing), 28; ink materials other than for printing, 474; flax packing, 24; asbestos, 39; paper, 2,267; rubber, 256; rope, 5; wax (sealing), 30; wools, 39; textile materials, 49; miscellaneous materials, 410.

The Bureau's chemical tests were made for about 70 Government bureaus and establishments, including practically every executive department, as follows: Agriculture, 24; Commerce, 906; Interior, 93; Labor, 44; Navy, 302; Post Office, 564; State, 1; Treasury, 495; War, 403; United States committees and commissions, 45; General Supply Committee, 610; Isthmian Canal Commission, 3,144; Government Printing Office, 1,685; other independent Government establishments, 5,491; State, municipal and other institutions and committees, 318; and private parties, 419.

During the past year there were distributed 1,633 iron and steel samples, 48 brass samples, 155 ore samples, and 90 sodium oxalate samples, as against 1,300 iron and steel samples, 57 brass samples, 183 ore samples, and 89 sodium oxalate samples distributed during the previous year. No samples for colorimetric and polarimetric standardization are included in these statistics. Since the chemistry division has now taken over the responsibility for the prompt shipping of these latter samples and is also mainly responsible for their preparation, it is intended to include them in subsequent reports from this division.

Miscellaneous Chemical Tests.

In addition to the routine testing mentioned above, certain miscellaneous tests were made for the Government and others, which were sufficiently thorough in character to make them partake of the nature of investigations. Among the subjects treated in this connection were metal polishes; the removal of stains from painted and varnished surfaces and marble; preparation of ink for marking metal time cards; preparation of specifications for imitation Damar varnish; methods of applying enamel to small articles, such as shoe buckles; kapok, its value in life preservers; rendering the paper of drawings and prints sufficiently transparent to enable blue prints to be made directly; a substitute for galvanizing; prevention of the rusting of iron; and the action of boiler compounds.

Publications.

The following papers and circulars have been published during the year or are nearly ready for publication, namely, "Hewettite, Metahewettite, and Pascoite, Hydrous Calcium Vanadates" (in cooperation with the geophysical laboratory of the Carnegie Institu-

tion of Washington, and published in the Proceedings of the American Philosophical Society); Scientific Paper No. 232, "Equilibrium in the System Lead Acetate" (in cooperation with the optical division); Technologic Paper No. 41, "Lead Acetate Test for Hydrogen Sulphide in Gas"; Circular No. 48, "Standard Methods of Gas Testing"; Distillation of Liquid Air in a Magnetic Field" (published in the Journal of the American Chemical Society, vol. 37, p. 1715); third revised edition of Circular No. 32, "State and Municipal Regulations for the Quality, Distribution, and Testing of Illuminating Gas"; "Technical Work of the Bureau of Standards in the Gas Field" (published in the Gas Record, vol. 1, p. 291); Circular No. 53, "The Composition, Properties, and Testing of Printing Inks"; Technologic Paper No. 45, "A Study of Some Recent Methods for the Determination of Total Sulphur in Rubber"; third edition, enlarged, of Circular No. 38, "The Testing of Mechanical Rubber Goods"; "The Determination of Oil and Rosin in Varnish" (nearly ready for publication); Circular No. 52, "Regulation of Electrotyping Solutions"; "Gas-Washing Apparatus with Enclosed Filter" (published in the Journal of Industrial and Engineering Chemistry, vol. 7, p. 534); "Apparatus for the Determination of Sulphur in Gas" (published in the Journal of Industrial and Engineering Chemistry, vol. 7, p. 620); "A Qualitative Test for Water by the Use of Acetylene-Cuprous Chloride Reaction" (Journal of the American Chemical Society, vol. 36, p. 2462); "The Colorimetric Determination of Acetylene" (nearly ready for publication); "A simple Stone-Frame Chemical Hood" (published in the Journal of Industrial and Engineering Chemistry, vol. 7, p. 1726); "The Preparation of Pure Iron and Iron-Carbon Alloys" (nearly ready for publication); "A Test of a Surface Combustion Furnace" (nearly ready for publication); "Determination of Carbon in Steels and Irons by Direct Combustion in Oxygen at High Temperatures" (published in the Journal of the Washington Academy of Science, vol. 4, pp. 393, 1914).

Transfer of the Work of the Contracts Laboratory of the Bureau of Chemistry to the Bureau of Standards.

On July 1, 1914, in accordance with congressional provision, the work of the contracts laboratory of the Bureau of Chemistry was assumed by the chemical division of this Bureau. Owing to the similarity of this work with that of the existing structural materials laboratory, it was deemed advisable to operate the two forces as a single unit until a plan for reorganization could be effected. This reorganization has been accomplished and the work is now proceeding in a satisfactory manner.

The New Chemistry Building.

Throughout the year a building committee consisting of members of the chemical staff of the Bureau, with the aid of the superintendent of the Bureau buildings and grounds, the architects, and the ventilating engineer, have been engaged in preparing plans for the new chemistry building authorized by Congress. The plans for the building have been completed and the specifications printed. It is

expected that the construction of the laboratory will begin by September 1.

6. ENGINEERING RESEARCH AND TESTING.

Physical Equations.

During the past year the following papers along the lines of technical thermodynamics and engineering physics have been published:

"Physically Similar Systems. Illustrations of the Use of Dimensional Equations," published in October, 1914, in which is considered an important theorem regarding the forms of complete physical equations, which is the most convenient statement, for practical use, of the principle dimensional homogeneity.

"Formulæ for the Windage of Flywheels," published on January 15, 1915.

"Model Experiments and the Forms of Empirical Equations," presented to the June meeting of the American Society of Mechanical Engineers.

These papers will all form parts of a more comprehensive paper to be published by the Bureau later.

A short paper has also been prepared on the dimensional theory of wind-tunnel experiments to accompany a series of experimental papers published by the Smithsonian Institution.

Aerodynamics.

Numerous requests for information or for experimental work on aerodynamics have been received; for example, on subway ventilation, testing of roof ventilators, the design of windmills and aero propellers, and the characteristics of aeroplane speedometers. Information has been supplied on some of these points and experimental tests have been made on air meters, anemometers, and electric fans. The most important of such requests and inquiries have come from the National Advisory Committee for Aeronautics. A report on existing types of aeroplane speedometers has been furnished to them and will be published later by the Bureau, and work is now in progress on the design of a new speedometer for use by the Army and Navy.

In the further development of aeronautics and aviation, many physical investigations must be carried on in cooperation with constructors and operators and in response to requests for physical information and numerical data suggested by their practical experience. It is important that the Government be able to have this purely scientific work done in its own physical laboratory, the Bureau of Standards.

While some of this work can be taken care of under the present conditions at the Bureau, to respond satisfactorily to the demands which are being made the Bureau must have an adequate equipment for experimental research in aerodynamics, and such an addition to its staff as will permit of important new investigations being undertaken as requested and without unreasonable delay. It is therefore proposed to establish a section of aerodynamics to take charge of this work.

Vacuum Cleaners.

Portable vacuum cleaners for use in public buildings are purchased by the Treasury Department under specifications which are based upon the results of an investigation recently conducted at this Bureau. As a result of the Bureau's work in this field manufacturers have introduced certain changes in the design of their machines which increase both their efficiency and capacity as shown by tests under operating conditions.

Radiator Traps Used in Connection with Vacuum Systems of Heating.

Information of decided practical value has been obtained in the investigation of radiator traps used in vacuum systems of heating. This work was undertaken at the request of the Supervising Architect of the Treasury. The special apparatus that was installed for conducting this investigation has given excellent results, and the study of the performance under operating conditions of 26 different makes of traps is nearing completion. The data obtained will be used in the preparation of specifications for radiator traps to be used in connection with the heating systems of Government buildings.

Anemometers as Speed Indicators for Aeroplanes.

At the request of the Langley Aerodynamical Laboratory, a report has been prepared on anemometers for use as speed indicators for aeroplanes. This report, which is based upon an exhaustive study of the various types of anemometers, including pitot tubes, will appear as a Bureau publication in the near future.

Water Current Meter Rating Station.

The testing of current meters, which was formerly conducted at Chevy Chase Lake, is now carried out in a reinforced concrete tank recently completed at the Bureau. This testing tank, which is 400 feet long, 6 feet wide, and 6 feet deep, offers excellent facilities for rating meters, particularly meters of special and delicate design such as are used by the Government bureaus to measure the velocity of ocean currents. The autographic recording mechanism designed at the Bureau and constructed in its instrument shops, and the electrically driven carriage with hydraulic gear for accurate speed control, constitute the most complete equipment for meter rating in this country. Although the new testing station has been in operation only a few months, meters for test have already been received from various parts of the United States and from Canada. The greater part of the Bureau's work in this field at present is for the Geological Survey and the Reclamation Service, but it is certain that the exceptional facilities offered by the new station will greatly increase the number of meters sent in by State governments and engineers.

Gasoline Engines.

The Bureau's laboratory for testing the power and fuel consumption of gasoline engines such as are used in automobiles, motor boats, and aeroplanes has been in operation for about two years. The electric absorption dynamometer used for this work was installed by

the Signal Corps of the War Department, and has been operated under the Bureau's direction. A number of gasoline engines have been tested, but the large demands made upon the limited engineering force have rendered it impossible to undertake any experimental work in this field.

Tests of Miscellaneous Instruments and Devices.

The greater part of the Bureau's work in this field consists in the rating of current meters, of which 285 were tested during the past year. In addition, 131 tests of miscellaneous devices were made, including steam, vacuum, and hydraulic gauges, fire extinguishers, vacuum cleaners, anemometers, tachometers, water meters, valves, and life preservers.

7. METALLURGY.

Fusible Tin Boiler Plugs.

An investigation has been completed and prepared for publication on the failure and deterioration of fusible tin boiler plugs. This safety device for preventing boiler explosions is widely used in stationary and locomotive boilers and is required on the marine boilers on all steamboats coming under the jurisdiction of the Steamboat-Inspection Service, which Service brought the matter to the Bureau's attention through the failure of a plug to operate on the steamer *Jefferson*, causing loss of life. Some 1,200 plugs, both used and new, were examined, and this investigation has shown that, although pure tin is called for in the specifications, it often is not furnished by the manufacturer. It appears that only 0.3 per cent zinc as impurity is sufficient to eventually cause the complete oxidation of the tin filling, thus rendering the plug dangerous, whereas strictly pure tin plugs will remain sound. Several of the specifications now in force are shown to be inadequate. It would probably we well to license a limited number of manufacturers of fusible boiler plugs whose product could be controlled by Federal inspection, and not permit promiscuous manufacture. At present the Steamboat-Inspection Service submits to this Bureau sample plugs from new manufacturers.

Properties and Standard Test Specimens of Bronzes.

The results of the investigation, undertaken at the suggestion of the American Institute of Metals, on the variations in foundry practice as influencing the properties of standard test specimens of the zinc bronze, known as Government bronze of composition 88 copper, 10 tin, 2 zinc, are embodied in a forthcoming technologic paper. The Bureau also has assisted in the preparation of the specifications for this bronze in cooperation with the American Society for Testing Materials. An extension of this work is outlined, consisting in the intercomparison of the properties of such specimens prepared from the same ingot metal, but by different foundries, according to a definite and uniform plan of procedure. This will afford information as to variations which may be expected in meeting specifications.

A metallographic examination has also been made, and the results are ready for publication, of the samples of zinc bronze (88 Cu, 10 Sn, 2 Zn) prepared at the Bureau by various methods. It would appear from this investigation that the presence and distribution

of oxides in the casting is the predominating factor determining its quality.

This bronze has also been studied to determine its microstructural changes accompanying annealing. The results, which will be published shortly, show that the bronzes are very different in their behavior from steel and show no recrystallization or "grain refining" unless they have been previously cold worked, as by rolling or hammering.

Radiation from Metals and Oxides.

The radiation intensities characteristic of the several metals and oxides, or their monochromatic and total emissivities, are of considerable metallurgical and pyrometric importance. The work described in last year's report on "The Emissivity of Nickel Oxide" has since been issued as Scientific Paper No. 224.

The same methods have been applied to iron oxide and published in Scientific Paper No. 249. Iron oxide in the spectral region $\lambda=0.65\ \mu$ is almost "black," having an emissivity varying from 0.98 to 0.92 in the range 800° to 1,200° C. The total emissivity increases from 0.85 at 500° C. to 0.89 at 1,200° C. The corrections to be applied to optical and total radiation pyrometers when sighted on iron oxide are as follows:

	500 °C.	600 °C.	700 °C.	800 °C.	900 °C.	1,000 °C.	1,100 °C.	1,200 °C.
Optical pyrometer	0	0	0	+ 1	+ 2	+ 4	+ 6	+10
Radiation pyrometer	+30	+30	+35	+35	+40	+40	+45	.....

The micropyrometer (see Scientific Paper No. 198) has also been adapted to the measurement of the monochromatic radiation of metals and oxides, it being possible to take observations rapidly and over a large temperature range on a quantity as small as 0.01 mg. presenting a surface of 0.25 mm^2. The results of observations on 23 metals and 12 oxides have been published in Scientific Paper No. 242, showing that, in general, there is no temperature coefficient of emissivity and that for several metals, including platinum, there is a discontinuity in radiation at the melting point. This would render the Violle unit of light, based on platinum brightness at its melting point, a variable standard.

The Quality of Platinum Ware.

The thermoelectric method of classifying platinum ware, described in the last year's report, has been supplemented by measurements on the loss of weight of platinum on heating, with the object of determining the specifications and best composition for platinum ware, such as crucibles, which are subject to loss of weight on heating; a phenomenon which is very troublesome to the analytical chemist and which reduces the accuracy of his results. This investigation, which was undertaken at the suggestion of the American Chemical Society, afforded incidentally an opportunity, through the many samples examined, to form an estimate of the purity of high-

grade platinum ware on the American market. Thus, of 164 samples examined, including a wide variety of objects, 43 pieces contained an equivalent iridium content of less than 0.5 per cent and 110 less than 2 per cent iridium. The loss of weight on heating for iron-free crucibles ranged from 0.71 mg. to 2.96 mg. per 100 cm^2 and per hour at 1,200°, the greater losses being for crucibles containing iridium and the lesser with those containing rhodium. From the thermoelectric measurements of purity, combined with a microscopic examination, the probable loss of weight for any platinum crucible can be predicted with sufficient accuracy for analytical purposes. It is suggested, for highest grade crucibles, that iron-free platinum containing 3 to 5 per cent rhodium be specified. This thermoelectric examination of platinum purity is now a regular Bureau test; also the Bureau's advice has been sought by several departments of the Government and other large users of platinum concerning purchases under this test.

Causes of Failures of Railway Materials.

In conjunction with the engineering and chemical divisions a comprehensive series of investigations of the causes of failure of railway materials has been undertaken, including some of the fundamental problems in the manufacture, design, and properties of rails, wheels, tires, and axles, as related to their failure in service.

During the past year considerable necessary equipment has been assembled and a start made on several problems, including sound-ingot research, rail-finishing temperatures, transverse fissures in rails, properties of cast iron, thermal analysis, and metallographic methods of examination.

A very important event in this connection was a meeting held at the Bureau May 22, 1915, attended by the technical representatives of 24 railway systems, at which the work of the Bureau on railway materials was discussed and a plan of cordial cooperation inaugurated, including the furnishing by the railways of statistics of failures and material for examination. It is believed that by thus working in cooperation with the railroads and gaining the benefits of their varied and extensive experience and technical advice, more rapid and efficient progress in the solution of the problems of the causes of failure of railway material will be made. The advantages of a centralized experimental laboratory which also has access to the material in service are manifest.

Causes of Failure in Car Wheels.

A study of car wheels is projected in view of the fact that they constitute one of the principal causes of railway accidents, and there are many matters of uncertainty as to best practice in manufacture and design. There are, for example, over 20,000,000 "chilled cast-iron" wheels in use in the United States and they are interchangeable from one railway to another, so that specifications should be rigid and uniform. Some of the items to be studied are statistics, foundry practice, mixtures used in manufacture, effect of sulphur on properties, braking and internal strains, strength of and best design, properties of hot cast iron, soaking pit practice, and relation of combined carbon to annealing. A beginning has been made on the last item.

Transverse Fissures in Rails.

The problem which the railway conference of May 22, 1915, considered the most urgent is the determination of the causes of "transverse fissures," a hidden defect or split in the rail which often makes its occurrence evident only by the rupture of the rail by a train. A series of questions on this subject have been submitted to practically all the railroads in the United States, asking for their experience, data and samples, and for suggestions as to methods of attack. The replies which are being received will be a most valuable guide in orienting this investigation, which will involve work in the laboratory, mill, and service, including trials of artificial producton of such fissures by several methods, metallographic and chemical surveys of rails containing fissures compared with sound rails, examination of rails which have withstood long, severe service, and the effects of mill practice, including internal strains, gagging, and the completion of the chemical reactions across the rail section as influenced by manufacture. It is also hoped to have the cooperation of the optics division in the determination of the variation of expansion coefficient across the rail section.

Finishing Temperatures of Rails.

The survey of American practice regarding the finishing temperatures and properties of rails, mentioned in last year's report, was presented before the American Institute of Mining Engineers and has been published as Technologic Paper No. 38. The subject of finishing temperatures is one of the greatest importance in rail manufacture, and the discussion of the subject was participated in by several of the most prominent authorities in the country; and this discussion brought out a general confession of ignorance of many matters connected with the relation of methods of manufacture to the resulting properties of rails. It is hoped to be able to aid in the solution of some of these outstanding uncertainties. In Technologic Paper No. 38, the "shrinkage clause" in rail specifications such as those of the American Society for Testing Materials (defining the finishing temperatures by the shrinkage of the rail) was shown not to fulfill the intended requirements of its framers in limiting the temperature to slightly above the recalescence point. The rail committee of the American Society for Testing Materials presented a report concluding "there is lacking anything which points to such decided differences in the quality of rails rolled at varying temperatures as theoretical considerations have led some of us to expect." The society has instructed its rail committee to cooperate with the Bureau in a further investigation of this important matter.

It is also proposed to study several allied questions, including the relation of rail section to the temperature distribution on cooling, and the relation of the latter to the completeness of the chemical reactions, internal stresses, and metallographic transformation for different sections and compositions of rails.

Sound Ingot Research.

The use of only sound steel ingots for the manufacture of rails and other structures, on which the safety of the public depends, is a matter of the greatest importance. With the cooperation of several

steel manufacturers, the Bureau has been enabled to compare the behavior and properties of several types of ingot, including the Hadfield form, consisting in (1) piping steel, (2) cast large end up, (3) suitable sink head with (4) air blast on charcoal and slag. This method produces an ingot, 90 per cent of which is physically and chemically sound. The results of this investigation, including also an examination of rails rolled from some of these ingots, were presented before the American Institute of Mining Engineers and also before the British Iron and Steel Institute. Opportunity has also been offered for a further study of this type of ingot by the Pennsylvania Railroad, which is to have rolled into rails 100 tons of Hadfield ingots, to be studied in detail by the Bureau.

Arrangements are also being made to study other processes of manufacture of sound ingots, such as the compression process of Mr. B. Talbot, of Middlesbrough, England, and the "hot-top" ingots of the Cambria Steel Co., together with an examination of the effects of such ingredients as vanadium and titanium.

It is believed that an impartial study by the Bureau of the methods of manufacture of steel ingots, blooms, rails, and similar products will be helpful in stimulating an improvement in manufacturing methods and should result in more rigid specifications being enforced for those products the use of which involves life hazard.

Test Ingot Investigation.

A matter of very great practical importance in the buying and selling of steel, involving acceptance or rejection of the material under specifications, is the determination of its analysis. The usual practice is to take for analysis a "test ingot" from the ladle before casting and assume this to be representative of the finished product. These test ingots vary greatly, however, in shape and size and quality, and it seemed desirable to endeavor to standardize this practice.

The study has been continued during the past year with the cooperation of the American Society for Testing Materials. Data have been collected regarding American practice in the matter of the shape and size of such ingots, methods of sampling, etc. Seventeen of the leading steel companies have cooperated in the work by furnishing sample ingots of various grades of metal. This first series examined represents ingots poured directly; that is, without the addition of aluminium, silicon, or other substances for rendering the metal compact and free from blowholes. Later the influence of such additions will be considered.

Fifty-five ingots have been examined up to date. This examination, so far, has been entirely metallographic, including the mapping out of the regions of segregation of sulphur (as an index of the segregation in general) and the determination of the presence of included "scale," oxides, etc., in the porous metal. Careful chemical surveys of selected types will supplement and confirm this work. Up to the present the investigation seems to warrant the conclusion that shape and size of the ladle ingots are minor factors and that the investigation of the subject of additions to the metal upon pouring to render the ingot sound and free from holes is the most satisfactory solution of the problem.

This work should be extended eventually by a comparison of "test ingot" analysis with that of the finished products. It would ap-

pear that, at least for certain classes of materials, such as rails, the "test ingot" method of analysis should be rejected in favor of the analysis of the finished product.

Foreign Railway Specifications.

A technological paper has been prepared on foreign railway specifications for rails, wheels, axles, and tires. This material was collected with the aid of the Department of State from the Governments or railway administrations of Austria-Hungary, Belgium, France, Germany, Great Britain, Holland, Italy, Russia, and Sweden. The circular contains a comparison and discussion of these specifications, including a summary of accident statistics, as well as translations of the foreign text of the specifications for rails, wheels, axles, and tires. It is expected the circular will be of interest to those responsible for and interested in the specifications for such railway material in the United States. In general, it may be stated that the foreign railway material, such as rails, wheels, tires, and axles, appear to perform the duty imposed upon them in a more adequate manner than is the case in America.

Failure of Structural Brasses.

A comprehensive study of the causes of failure in service of structural brasses and bronzes has been undertaken by the Bureau. The costly experience of the New York Board of Water Supply on its Catskill Aqueduct project as well as the failures of bronze in the Minneapolis filter plant and elsewhere, the former of which has been widely advertised, raised the questions whether the bronzes used for such structural purposes were suitable for the purposes for which they were designed, whether the specifications were inadequate, or the methods of manufacture at fault. There appears to be a very serious lack of reliable data upon which to draw up specifications for this type of material and the ordinary tests do not usually give an indication of the true permanency of such bronzes which may easily be spoiled in manufacture.

The Bureau has had the cooperation of a number of brass and bronze manufacturers who have furnished material made, as suggested by the Bureau, in several ways; and the Bureau has been able to obtain failed material from several sources, including the New York water board, city of Minneapolis, and the Navy Department.

The relation of the presence of internal stresses to methods of manufacture and subsequent heat treatment have been carried out for numerous samples from various sources. It would appear that the presence of these internal stresses, sometimes associated with corrosion, is largely responsible for failure. It has also been shown these stresses can be removed by annealing, without serious detriment to the physical properties. The effects of corrosion on stressed brasses is also to be studied. There is in this problem of defining the just limitations of nonferrous alloys for structural and other purposes a wide field of research.

A preliminary account of the work already done is being prepared for publication.

Preparation of Pure Iron and Iron Carbon Alloys.

It is shown that previous work on the iron-carbon diagram is unsatisfactory because of the great variation in the materials used. It was, therefore, thought necessary to produce a series of alloys of great purity to form the basis of a redetermination of the diagram at the Bureau of Standards. The general method consisted in melting electrolytic iron with sugar carbon in magnesia crucibles. The electrolytic iron was prepared from ingot iron anodes in a chloride bath with or without the use of porous cups. The operation of melting the iron with carbon gave great trouble at first because the ingots obtained were full of blowholes and contained considerable quantities of impurities. These difficulties were overcome by melting in a vacuum furnace and making crucibles of especially pure magnesia, made and calcined at the Bureau of Standards. A satisfactory procedure was finally worked out and a series of alloys prepared of the composition Fe+C=99.96 per cent.

The Iron-Carbon Equilibrium.

During the early part of 1914 work on the thermal analysis of pure iron was completed and the thermal study of the iron-carbon series was started. A large number of alloys ranging from 0.02 to 1.8 per cent carbon were made up and observations taken by the inverse rate and derived differential methods for some 250 heating and cooling curves. These observations have all been plotted and a study of the effect of rate on the location of the critical points has been started. Upon the completion of this work and a study of the effect of decarbonization, the results will be ready for publication. Work on this problem has been delayed or interrupted by the preparation and installation of exhibits for the San Francisco exposition and by testing.

Determination and Distribution of Carbon in Steels and Irons.

The improvement of analytical methods in metallurgical chemistry are of great economic significance as well as of scientific interest. Two methods for the rapid determination of carbon in steels have been devised, one by direct combustion in oxygen at high temperatures, a preliminary account of which has been published; the other by a conductivity titration method, which is in preparation.

The relation of the amount of graphite to the heat treatment of cast iron is of importance in the manufacture of chilled cast-iron wheels. Some preliminary work has been done in cooperation with one of the wheel manufacturers.

The Physical Properties of Pure Iron and Copper.

The pure iron made at the Bureau is being studied for several of its physical properties. Scientific Paper No. 236 has been published describing the experiments on the electrical resistance and temperature coefficient of pure iron between 0° and 950° C. These experiments, carried out with a precision of 1 in 300,000, demonstrate the nonexistence of transformations below 757° C., show the Ac_3 and Ar_3 transformations to begin at the same temperature 894° C. and extend over 25°, and accompanied by a decrease in resistance on heating and an increase on cooling through the A_3 transformation. The A_2 trans-

formation, the interpretation of which is still in dispute, is evidenced by a very sharp cusp at 757° C. in the temperature coefficient curve, or by an inflexion in the resistance curve.

Exact measurements have been taken of the resistance of copper in the interval 0° to 100° C. with the object of detecting allotropic changes which have been reported by Prof. E. Cohen, of Utrecht.

Melting Points of Steels and Refractory Elements.

The determination of the melting points of a considerable number of steels of practical importance has been undertaken and is nearly complete. Also the melting points have been determined, by means of the micropyrometer, of practically all of the refractory chemical elements. It is hoped to be able to publish these results shortly.

A Test of a Surface Combustion Furnace.

In view of the fact that the surface combustion process appeared to offer many advantages for high-temperature laboratory furnaces, in which the Bureau is interested, it was decided to submit a crucible furnace of this type to a thorough test. For the purpose, the furnace was equipped with meters on the gas and air lines, and with a chimney to permit the collection of flue-gas samples. In several runs the mixture proportions were maintained constant while varying the rate of gas consumption. Temperatures were read by a Holburn-Kurlbaum optical pyrometer. The highest temperature reached was 1,675°, at which point the muffle failed. The test established that complete combustion could be attained without excess air, that the best air-gas ratio was 5·5, and that a 20 per cent excess of air caused a lowering of furnace temperature of 100°. An account of this test, which is the first of its kind, is in course of preparation.

Nomenclature of Nonferrous Alloys.

A paper which evoked considerable discussion was presented before the American Institute of Metals on the "Progress in the Nomenclature of Alloys." There is great need for systematizing the naming of complex alloys and of their constituents. The coining of new names and the use of proper names is being discouraged, and it is probable that from the several suggestions which have been made a rational system of nomenclature may be worked out which meets the needs of the foundryman on the one hand and is correct scientifically on the other hand. The Bureau of Standards in cooperation with the American Institute of Metals is considering the matter, and it has been hoped to bring about uniformity for the English-speaking countries through the cooperation of the British Institute of Metals and its allied societies; and possibly, at least as concerns some of the fundamental principles, international agreement may be reached through the active advocacy of the subject by the editor of the International Journal for Metallography.

Investigation of Molding Sands.

In cooperation with the American Institute of Metals, the Bureau has begun an investigation of the properties and methods of testing molding sands, with the object of finding out the characteristic qualities of such sands as have proved serviceable and endeavoring to put

on a better scientific basis the classification of molding sands. A preliminary report will be presented at the fall meeting of the American Institute of Metals.

Pyrometric Standard Samples.

In response to numerous requests, arrangements are being made for the preparation, testing, and certification of certain pure metals of known and exactly determined melting points, such as tin, zinc, aluminium, silver, and copper, as pyrometric standards for distribution for the calibration of pyrometers. Several firms have offered to assist in furnishing such samples. The metallurgical and heat divisions will cooperate in this work.

Specifications for Metals.

The Bureau has received many verbal and written requests for copies of its specifications for various metals and alloys, and surprise is often expressed that the Bureau has no specifications of its own for these materials. There are many lines of specification work in metals which it would be highly desirable for the Bureau to take the lead in framing specifications which would serve as models for other branches of the Government service and elsewhere. This would require a considerable increase in the staff. Some of this work is, of course, now done in connection with committees of the several technical societies, but the work could well be systematized. As at present conducted, it is somewhat haphazard and accidental and often is not backed by sufficient experimental evidence such as the Bureau could furnish.

Cooperation with Manufacturers on Nonferrous Metals.

A very important feature of the work in metals at the Bureau has been the cooperation with manufacturers on nonferrous metals, including representatives of the American Institute of Metals, the American Chemical Society, the American Institute of Mining Engineers, the American Society for Testing Materials, and the American Electrochemical Society. Two well-attended meetings have been held during the past year at the Bureau, which has greatly aided in suggesting and mapping out lines of work, securing typical materials or samples, and obtaining the aid and benefit of the experience of many manufacturers for several problems in which the Bureau is interested. Very cordial and reciprocal relations have thus been established, which are of mutual benefit.

Metallurgy and Chemistry of Platinum-Group Metals.

Provision should be made for the study of the metallurgy and chemistry of the metals of the platinum group. This would require the installation of special furnaces and refining apparatus in addition to the chemical equipment, and the services of two or three men, one of whom should be skilled in platinum refining.

Systematic Investigation of the Properties of Metals.

Knowledge of the properties of even the more commonly used metals and alloys, especially at high temperatures, is very meager, and their determination requires, in many cases, elaborate and costly experimental arrangements and considerable skill.

The Bureau is in receipt of many insistent and reiterated demands for many of these constants which can not be obtained elsewhere and which are needed in many lines of practical work. There is no way in which the metallurgical division of the Bureau could better serve the community than by inaugurating a systematic series of experiments on the determination of the physical constants of metals.

This work should be divided into two correlated classes—(1) the gathering and digesting of existing data, much of which exists only in private records, especially of some of the larger manufacturing companies (the Bureau should become a clearing house for the assembling and publishing of data thus made available); (2) actual experimental investigations by the Bureau.

That the country needs and expects the Bureau to take up this work on a more extensive and comprehensive scale than has been hitherto possible is evidenced by the fact that representatives of five of the principal scientific and technical societies have pointed out the necessity for such work, as have engineers separately. A resolution was passed by the iron and steel committee of the American Institute of Mining Engineers "that the Bureau of Standards be requested by this iron and steel committee to give attention to determining some of the lacking chemical and physical data concerning iron, more particularly the latent heat of fusion, specific heat in the liquid state, and heat conductivity up to the melting point, of pure iron and typical steel and cast iron."

It is also felt that such determination of physical constants when made by the Bureau will be unbiased, exact, and carry the weight of the authority of an impartial body of experts. This is an important phase of the matter, particularly when dealing with products that come into competition with each other.

Several manufacturers have expressed the willingness and urgent desire to furnish in quantity the pure materials required, such as zinc, aluminium, and copper, which would be especially purified for the purpose. A special fund should be provided for this purpose.

Aid Rendered the Public by Metallurgical Investigations.

Most of the investigations being made of metals have been undertaken at the request of technical societies, departments of the Government, railroads, manufacturing firms, or individuals; and in all cases the problems being studied are of general interest and represent endeavors to find answers to specific questions of considerable importance to large classes of people.

As examples may be mentioned the study of structural bronze and brass failures, which is of far-reaching importance in defining the proper use of and specifications for these materials, first undertaken at the instance of the board of water supply of the city of New York and the city of Minneapolis, and later with the cooperation of many manufacturers; the investigation of causes of failure of fusible tin boiler plugs, requested on behalf of the Steamboat-Inspection Service, but of interest to all users of boilers employing this safety device; and the determination of the quality of platinum ware, started at the request of the American Chemical Society, and of interest to all users of such material.

Metallurgical Testing.

The following tests were completed during the year:

Name.	Heat treatment, thermal analysis.		Metallographic.				Fusible plugs.	Brass and bronze failures.	Miscellaneous.	Grand total.
	Non-ferrous metal.	Irons and steels.	Rail-failures.	Identification method and process of manufacture.	Metal failures.	Miscellaneous.				
For the Government:										
Panama Canal	.....	2	.....	104	.....	.....	.....	.....	.....	.....
Bureau of standards	.....	45	.....	24	.....	.....	.....	.....	.....	.....
Miscellaneous	5	3	2	6	9	.....	1,063	.....	2	.....
Total	5	50	2	134	9	.....	1,063	.....	2	1,265
For the public	.....	38	.....	7	.....	13	.....	173	1	232
Grand total	5	88	2	141	9	13	1,063	173	3	1,497

Of these 1,497 test items, 1,265, or 85 per cent, were for Government departments. The Government tests were distributed among the Isthmian Canal Commission (106), Bureau of Standards (69), Steamboat-Inspection Service (1,062), Bureau of Lighthouses (5), War Department, Quartermaster General's Office (6), Interstate Commerce Commission (3), Naval Inspector of Ordnance, Philadelphia (3), and 1 or 2 each for the chief clerk's office, Department of Commerce; Naval Supply Depot, Brooklyn; Naval Gun Factory, Washington; Bureau of Mines; Superintendent, Capitol and Grounds; National Zoological Park; corporation counsel, District of Columbia; Post Office Department; and Supervising Architect's Office, of the Treasury.

Several of these tests, particularly of failed materials, necessitated elaborate researches, and will serve as the basis for publications concerning the various types of metal failures.

Information Furnished as to the Properties of Metals.

The metallurgical division of the Bureau has furnished by correspondence much information concerning the properties of metals, and has received many visits from representatives of firms desiring similar data. For example, in one month representatives of the following interests visited the Bureau to ask its advice: A watch company, concerning nonmagnetic and nonexpansible alloys; a steel company, on the improvement of rails with titanium; a brass company, as to metallographic methods; a car-wheel company, concerning railway materials and metallographic standards; a car-wheel company, in regard to chilled wheel design and service; a steel company, as to temperature control in the manufacture of ordnance; a brass company, concerning properties of nonferrous alloys, etc. Others have visited the Bureau to become acquainted with its methods

of testing and research, among them representatives of railroads, steel works, universities, instrument manufacturers, etc.

Typical questions handled by correspondence have been the improvement of malleable iron, from a manufacturer; aluminium disease, from a farmer; paint for metals to stand 800° F., from an enameling firm; case hardening and composition for rock drills, from a mining company; bronze bearings for heavy grinding machines; alloy that can not be remelted at original melting temperature; fusible boiler plugs data, from manufacturers; strength of vanadium steel, from an engineer; cooling curves of ordnance steel, from an ordnance officer; suitable steel for guy rods; soldering of iron sheets; failure of locomotive boilers by cracking at seams; case hardening of machine steel; alumina in steel, from a steel company; properties of forged wrought iron; equivalence of Ni and Cr to carbon in hardening rails, from a railroad; numerous inquiries concerning foundry practice, both from iron and brass foundries; abrasion of metals; expansion of metals with time and temperature, from a railroad company; methods of manufacture of various alloys; melting points and heat treatments of steel; suitable metals for printing plates; cutting metals with metallic disks; suitable resistance wires; substitutes for zinc for various uses; metallic thermostats, from an instrument manufacturer; bearing metals for watches and for locomotive parts; properties of molybdenum, from a handbook compiler; composition of a white nontarnishing alloy, from a manufacturer, etc.

Metallurgical Publications.

The following publications have been issued during the year: Technologic Paper No. 38, on "Observations on Finishing Temperatures and Properties of Rails;" Scientific Paper No. 224, "Nickel Oxide;" Scientific Paper No. 242, "Measurements with the Micropyrometer;" Scientific Paper No. 249, "Iron Oxide;" Scientific Paper No. 236, "Electrical Resistance and Critical Ranges of Pure Iron;" "Progress in the Nomenclature of Alloys," published in the Transactions of the American Institute of Metals, Vol. VIII, p. 46, 1914; "Determination of Carbon in Steels and Irons by Direct Combustion in Oxygen at High Temperatures," published in the Journal of Washington Academy of Sciences, vol. 4, p. 393, 1914; "Sound Steel Ingots and Rails," published in the Proceedings of the American Institute of Mining Engineers and the Proceedings of the Iron and Steel Institute of Great Britain. Other papers in course of preparation and in press are "Characteristics of Radiation Pyrometers;" "A Study of the Quality of Platinum Ware;" "An Investigation of Fusible Tin Boiler Plugs;" "Standard Test Bars of Zinc-Bronze: 88 Copper, 10 Tin, 2 Zinc;" "Some Foreign Railway Specifications: Wheels, Rails, Axles, Tires;" "The Microstructural Changes Accompanying the Annealing of Bronze: 88 Copper, 10 Tin, 2 Zinc;" "Failure of Structural Brass;" "Preparation of Pure Iron and Iron Carbon Alloys;" "A Test of a Surface Combustion Furnace;" and "Methods of Testing Molding Sand."

8. STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

Structural Steel Column Tests.

An important investigation now in progress which is of value to the engineering and architectural professions consists of a 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 the American Society of Civil Engineers comprises 9 different types of cross section. With one exception, 18 columns of each type have been fabricated for testing, 9 of light and 9 of heavier structural shapes. The 9 columns, both of the light and heavy kind, are made in 3 different lengths, so that there are 3 columns of each type and weight of section having the same length. During the progress of this investigation it was decided to extend this series of columns by 24 additional columns now being fabricated. These columns will be of the same types as those already furnished, but some will have different lengths and others will be made of heavier structural shapes.

The American Railway Engineering Society's columns comprise 18 latticed columns with rectangular bearing plates at both ends. Only one type of cross section but of two different weights of structural shapes has been tested. Both light and heavy columns are made in 3 different lengths, there being 3 columns of each length and weight of cross section. Thirty-six additional columns of this type, but modified in some single detail, are now being fabricated for the purpose of determining the effect of such modifications on the strength of the columns.

In addition to these column investigations, a large number of steel bridge columns have been tested in cooperation with prominent engineers. The columns are facsimiles of members from long-span bridges which are being erected or soon will be erected in America. The reports on the data and results of these tests, when completed, will be very valuable to bridge designers, as such data on large size columns have not been available before.

The purpose of these tests is to determine the best forms 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.

Although the testing of these columns consumes much time, since it must be done very carefully in order to secure reliable results, this investigation has made good progress during the past year. More than three-fourths of the two series of columns have now been tested. The results of these tests show that with one exception the columns made of the heavier structural shapes fail at loads per square inch of cross section which are about 10 per cent less than those which produce failure of the columns of the same type but of lighter section. The work has not progressed far enough to admit of drawing any

definite conclusions from the tests, and it may be necessary to again extend the present program of the investigation before arriving at a final interpretation of the results.

Tests of Large Columns for Long-Span Bridges.

Through the cooperation of several consulting engineers and manufacturers with the Pittsburgh branch laboratory, it has been possible during the last three years to carry to completion an investigation upon the strength and behavior of 18 large bridge columns when under loadings. The columns varied in size from 50 to 120 square inches in cross section, and were constructed of various alloys and high-carbon steels, some of the specimens being the largest ever tested. These 18 specimens corresponded throughout with certain top chord members selected from the following long-span bridges recently erected in America: The Municipal Bridge, at St. Louis; the Chicago, Burlington & Quincy Railroad Bridge, at Metropolis, Ill.; and the new bridge at Memphis, Tenn. In carrying out this investigation a study was made of the action of the columns as a whole to determine the relation of maximum loads to yield points of the grades of steel used. The elastic coefficients of the "built-up" members were found and the causes of initial strain induced in fabrication by the driving of rivets were analyzed. The laws affecting the distribution of stress and strain in the lattice, pin plates, and other details were studied with reference to the efficiency of these particular types of details used by their designers. Heretofore the inadequate capacities of American testing machines have imposed restrictions which prevented tests being made on large columns to the full maximum load at failure. Many of the present columns sustained from 3,000,000 to 6,000,000 pounds before collapse, and the derived data covering the behavior during tests will be of value to bridge and consulting engineers and manufacturers who are engaged in the construction of large railroad bridges. The research will also afford practical data for a proper formulation of the real mechanics of the column. These mechanics have in the past largely been based on purely theoretical considerations founded upon inductions made from the results gotten in the case of small laboratory specimens, there being but few systematic investigations previously made upon large columns of the type here considered.

Causes of Failure of Railway Materials.

The investigation as to the causes of failure of rails and other railway material has been continued during the past year. Numerous specimens of rails which failed in service have been received by the Bureau from several railway companies who offered their cooperation and assistance in this work. The failure of each of the specimens furnished was caused by the formation of transverse fissures in the interior of the rails and the Bureau is now endeavoring to ascertain under what conditions this type of failure is produced. Special shop equipment to facilitate the preparation of the specimens for the necessary chemical, microscopic, and physical tests has been recently installed. The results of this investigation will contribute toward safer railroad communication.

Standard Test Specimen for Cast Bronze.

The investigation made by the Bureau at the request of the American Institute of Metals preliminary to the establishment of a standard test specimen for cast bronze has been completed. About 800 specimens were prepared from a typical bronze consisting of 88 per cent of copper, 10 per cent tin, and 2 per cent zinc, and tested for ultimate strength. The results of these tests taken in conjunction with the results of the investigation of the metallurgical division led to the adoption of a certain form of cast test specimen as a standard for such materials. (See also "Metallurgical investigations.")

Influence of Time in Testing Steel Specimens.

The investigation made by the Bureau in cooperation with the American Society for Testing Materials to determine the effect of the speed of application of the load on the yield point of a steel specimen in tensile tests has not yet led to any definite conclusion, the results obtained so far not being sufficiently concordant. The yield point is the load in pounds per square inch at which a flow of the metal occurs when subjected to tension or compression. The purpose of this investigation is to ascertain the best speed of applying the load when making commercial tensile tests of various kinds of steel.

Behavior of Spring Steel under Repeated Static and Dynamic Stresses.

Work has been continued 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. The steel is being studied in the quenched condition as well as in its final state after being drawn. This work has brought out some difficulties, the solution of which it is hoped will advance our theoretical knowledge and improve the practice of heat treatment. This investigation has been carried on jointly at the Bureau and the Altoona shops of the Pennsylvania Railroad on certain locomotive springs which have been a source of considerable trouble up to the present time.

Calibration of Testing Machines.

It is desirable to test the accuracy of the reading of testing machines from time to time, especially during the course of a long investigation. With this point in view, the Bureau has secured apparatus for testing machines up to 50,000 pounds capacity and has undertaken the design and construction of apparatus with which it hopes to be able to standardize its own machines as well as those of the public to a point which lies as far beyond the 50,000 pound limit as may be necessary. Considerable progress has been made during the past year in this direction, so that the Bureau will soon be ready to standardize machines to 200,000 pounds capacity.

Information Regarding the Strength of Metals and Their Alloys.

Much assistance has been rendered by the Bureau during the past year in the form of answers to correspondents seeking information as to the strength and other properties of metals and on allied subjects. These inquiries were received from Federal Government de-

partments, municipal and State governments, universities and schools, engineering societies and research laboratories, corporations, and private individuals.

The inquiries relate to a wide range of subjects. Many were requests for technologic papers issued by the Bureau and sources of engineering literature printed elsewhere. Specifications for various materials, such as pipes, steels, hard-drawn copper bars and wires, hardware, tools, timber, materials for machine parts, and helical springs were often requested and on several occasions the Bureau was asked to interpret the existing standard specifications for materials and methods of tests. The Bureau's opinion has been frequently sought regarding the feasibility of various new devices, such as waterproof piles, devices for pneumatic riveting, and welding joints. Inquiries have been made concerning the testing machines, methods of testing, and kinds of testing apparatus needed for particular purposes. Information as to the cause of failure of manufactured materials has been the basis of many requests.

Tests on the Strength of Materials.

The test of compression and tensile strength, transverse bending strength, and hardness made at the Washington laboratories were for practically all departments of the Government. Over 200 tests were made on ferrous metals. These tests included, besides the usual specimens of different steels, tests of a jack cable reel, steel and galvanized iron wires, shafting, rollers, horseshoes, rail specimens, screw-box collars, header test bars, cast and malleable iron bars and bolts. One hundred and eighteen tests of nonferrous metals were made, such as bronzes and brasses, monel metal, bronze sash chains, and copper wires and plates and aluminum bars; 28 tests of sundry materials, such as porcelain insulators, vulcanized fiber, micanite, glass rings, and timber; compression tests of two large 10-inch glass cubes used for the insulation of radio towers, and tensile tests of 15 hemp ropes have been made. Besides, more than 300 pieces of structural steel for two Federal buildings, now being erected, were inspected; 5 testing machines having capacities of 100,000, 200,000, 400,000, and 800,000 pounds, the last being the Emery machine at the Watertown Arsenal, were calibrated or compared with the Bureau's machine; 3 jackscrews were tested for lifting capacity and 3 large bridge columns for ultimate strength.

Numerous tests of a general routine nature at the Pittsburgh branch were made for various departments of the Government and for manufacturers or individuals, these covering 290 tests of manila rope ranging in diameter from one-half inch to 3½ inches, 25 tests of wire cables, a number of tests of porcelain insulators for wireless transmission towers, and numerous miscellaneous tests upon steel and iron bars, granite blocks, as follows:

In connection with the work of the cement division, there were made 750 tests upon standard 6-inch concrete cylinders, 100 6-inch cubes of concrete, and 1,350 tests of 2-inch cement cubes. There were made numerous tests for manufacturers, these consisting of 12 tile walls, 6 feet long and 10 feet in height, both transversely and under compression; 4 transverse tests on street-car rails to determine efficiencies of various methods of electric welding, and a number of

tests of brick of various types. Four large hydraulic jacks of 40 internal diameter to be used in connection with the erection of long-span bridges were tested under proof loads to determine the action and efficiency of the cylinder packing rings. Twelve car couplers were tested under proof loadings, and a number of miscellaneous tests, aggregating about 100 specimens, were made on specimens of steel for rolls, cast-iron specimens, granite and limestone cubes, hollow tile, flexible casing for lamp cord, etc.

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. If this specification or a modified form is finally agreed upon, it will result in one recognized American standard instead of several as at the present time, with its attending advantages to the cement industry as well as the engineer. 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.

Hydraulic Cements Other than Portland Cement.

In the investigations under way dealing with Portland cement it has been necessary to determine the properties of the silica-alumina-lime compounds other than present in normal Portland cement. The result has been the finding of some very interesting lime-alumina compounds which developed very hard dense mortars which have a very high strength at early periods. The introduction of moderate amounts of silica and iron oxides into these serves to increase still further the high strengths which are obtained in compression, and also results in the production of ternary compounds which seem to have hydraulic properties of considerable value. A survey of these less known and seldom used compounds has been but preliminary, although the results have justified further work which was carried on at the Pittsburgh branch during the year with burnings made in the rotary kiln.

Further Studies of the Hydration of Portland Cement.

There was published during the past year a paper on the Hydration of Portland Cement. This represented the results of an investigation, carried on largely during the previous year at the Pittsburgh branch, dealing with the products of the hydration of the constituents of Portland cement clinker. There was no quantitative relation established between the products of hydration and the strength produced. During this year, however, the constituents ordinarily present in clinker were prepared, after much difficulty, in sufficient amounts to make sufficient tensile specimens to allow breaking at periods as late as one year. These constituents were tested, not only alone, but when mixed in about the proportion as found in normal

cements. Furthermore, the rate of hydration was followed by frequent microscopical examinations and the amounts of hydration determined by determinations of the amounts of water chemically combined. The results obtained confirm in almost every detail the deductions and predictions made in the paper already issued.

Clinkering Temperature of the Raw Mixes Used by Portland Cement Manufacturers.

Owing to the nature of the flame used in the manufacture of Portland cement, it is almost impossible to determine the temperature at which the raw mix is heated to clinker. This flame is in the nature of a cone surrounded by partially burning coal dust which almost entirely obscures the clinker at the hottest part of the kiln. But the temperature at which the proper combination of the various elements of the raw mix takes place is of great interest, especially when considered in connection with its lowering or raising produced by changes in composition. Seventy-three raw mixes have been burned at the same temperatures and the resulting clinker examined. This data is now being examined in connection with the composition of the mixes. There is also being made the melting (softening) point of these mixes. This work is being carried on with the Pittsburgh branch laboratory experimental kiln.

The Effect of Varying the Composition of Raw Mixes Used in Portland Cement Manufacture.

One of the more comprehensive studies of the Pittsburgh branch of the Bureau of Standards is determining the effect on the general properties of Portland cement of changes in the composition, which carries with it the determination of changes in the kind and amounts of the various constituents normally present. In this investigation 74 different cements have been made in the experimental plant of the Bureau. These have been examined petrographically, chemically, and their strength producing properties determined—as neat cements, mortars, and concretes. The 180-day specimens of all the cements have been broken, and consequently it will be possible to publish the results of the investigation, though specimens have been made for much longer periods which will entail the issue of the supplemental papers.

There have been included in this investigation three series of burnings, of which it is thought advisable to issue the results separately. One of these deals with white Portland cements, which differ from normal cements largely in their very low iron-oxide content. To make the investigation a little more comparative, there will be included some results obtained from burnings of very low alumina and high iron-oxide content.

The other two series deal with the important matter of the magnesia content of Portland cement. In these series there are burnings of cement of very low magnesia content and of a content as great as 25 per cent. It may not be anticipating too much to say that the limits for the magnesia content as specified in all standard specifications are well within the amounts which produce any injurious effects.

Suitability of Various Clays, Limestones, etc., for Making Portland Cement.

There are frequent demands made upon the Pittsburgh branch of the Bureau for the rendering of an opinion in regard to the availability of various materials for the manufacture of Portland cement. However, the Bureau has not yet made any detailed investigation of this character for the public, since when the inquiry is answered by a general statement in regard to the cost of building a new cement manufacturing plant and placing a new brand upon the market no further information is wanted. It is not generally understood that a deposit of raw material sufficiently large to last for 20 years for a plant turning out not less than 1,000 barrels per day—which is the smallest plant unit that would make adequate returns on the investment—is absolutely necessary. The deposit should also be examined carefully by a geologist to determine its uniformity in composition, since lack of this would produce excess cost of manufacture and other difficulties resulting in a lack of uniform cement. While the Bureau is very willing to make trial burnings of raw materials, it advises first a careful survey of the deposit, the determination of the likelihood of interesting sufficient capital in the proposition, and a survey of the neighboring market.

Investigation and Testing of Cement, Concrete, and Stone.

The work in the cement section is of three kinds:

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

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

(*c*) The testing of samples of cement submitted by various Government offices to determine as to 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.

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 Association of American Portland Cement Manufacturers 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 drain tile made under the Bureau's supervision were installed in concentrated alkali soils in Colorado, Montana, Wyoming, Arizona, Washington, New Mexico, and Utah. The results of the first year's tests published in Technologic Paper 44 show that concrete will disintegrate in some of these soils unless the

best of materials are used and special care is exercised in the fabricating of the concrete. Additional tests are to be made from year to year and the report amended as results are available. As an extension of this work short concrete columns are to be fabricated and installed during the ensuing year on projects in Colorado, Wyoming, Nevada, South Dakota, Montana, and New Mexico. These are made under various conditions and are to be inspected after exposure for various periods.

Standard Cement Sieves.

As a result of the further investigation of the standard 200-mesh sieves results of which were published in Technologic Paper 42, it was found desirable to change the specifications for standard sieves and require a given uniformity when tested with a standard fineness sample. This modification of specifications has benefited the testing laboratory by insuring greater uniformity of results.

Standard Fineness Sample.

As a result of requests for a standard fineness sample which could be used by laboratories for checking their sieves and operators, an investigation was made of the suitability for this purpose of various materials, such as ground quartz, alumina, burned clay, cement, etc. This investigation resulted in the adoption of such a sample which is now available to the public in two grades. There has been considerable demand for these samples since their preparation in December, 1914.

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. It will probably be a year or more before conclusive results will be available.

Granular Analysis of Cement.

Investigations have been continued with the granulometric analyzer. Much work has been done with the object of making the analyzer more compact and convenient for laboratory use. The proper shape of bulb, the effect of abrasion of particles on the results of analyses, effect of differences in specific gravity of cements on the sizes of particles blown off and the least height of stack that may be used, were investigated. In connection with the specific gravity and height of stack investigations, more than 10,000 cement particles were measured with the microscope. The results of these investigations have been reported in Technologic Paper 48.

In addition to work done with the analyzer as a part of the programs of investigations by the Bureau of Standards, work has also been done in connection with investigations by several cement companies.

"Flour" determinations have been made on samples of litharge, red lead, hydrated lime, ground sand, etc.

The air analyzer may be said to supplement sieve determinations of fineness, being capable of producing much finer separations than those obtainable with the 200-mesh sieve. 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.

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 an advisory committee consisting of representatives from the Government, engineering societies, the Associated Metal Lath Manufacturers, the Association of American Portland Cement Manufacturers, the Gypsum Industries Association, the National Lime Manufacturers Association, the Hollow Tile Manufacturers Association, and a number of plastering contractors. The recommendations of this committee have been followed in the execution 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 being constructed of terra cotta hollow tile, monolithic concrete, brick, gypsum block, plaster board, and wood and metal lath, and will be plastered with a number of typical stuccos. The work will be carried out under the supervision of the advisory committee, and it is anticipated that the finished panels will represent the best examples obtainable of exterior stucco construction. The stucco panels will be completed in the fall of 1915; later the interior of the structure will be available for tests of interior plasters on walls and ceilings. Results will not be available for a year or more.

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 conditions. 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. The results obtained show that changes in the moisture content of the concrete has greater effect upon the volumetric expansion or contraction than the normal atmospheric variation in temperature between seasons. The maximum expansion of concrete occurs in the early spring and maximum contraction in midsummer. Further measurements will be needed to determine the absolute quantitative effect of moisture and temperature conditions.

Strength of Reinforced Concrete Structures.

An investigation of full-size concrete structural members of various design to establish the laws governing their behavior was inaugurated. An advisory committee has been organized, composed of prominent engineers expert in concrete design, to act with the Bureau in the execution of the program. A thorough and exhaustive series of tests will be made on numerous full-size members of reinforced concrete construction in the form of both individual and composite structures. The work is in a formulative stage and no results are yet available.

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 and the results available to date have been published as Technologic Paper 47. 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.

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 this year and the results to date have been collated and will be published in the near future. 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 standard Portland cement. The difference in strength of the two concretes becomes more marked as the ratio of the cement to aggregate decreases.

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. Results of the investigations will probably be published in State reports and subsequently in Bureau papers as the results accumulate.

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. 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 ensure 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., is 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.

Effect of Sea Water on Concrete.

The investigation of the effect of sea water on concrete has been continued by inspecting many concrete structures along the Atlantic and Pacific coasts of the United States, the coast of Nova Scotia and New Brunswick, by careful investigation through physical examination and tests of structures which had failed, and collating information on the condition of concrete structures exposed to sea water in various ports of the world. These data are being obtained through the various consular agents, and reports have been received on a large number of structures. It is anticipated that during the ensuing year a report will be prepared showing the conditions under which concrete should be used in order to have permanency under sea-water exposure. The results of this investigation will be of value to the Government and all engineers interested in marine construction.

Fusion of Concrete.

The Bureau was asked to investigate the reported fusion of concrete in a burned building. Since the fusion of concrete had never been observed under such conditions, an investigation was made. It was found that the concrete had apparently fused in several of the buildings where the fire was known to have been of exceptional severity and long duration. Laboratory investigation upon samples of unexposed concrete from the same buildings showed that the concrete would fuse at a temperature of approximately 1,240° C. This comparatively low fusion temperature was due to the trap-rock aggregate. It was evident from the melted steel that temperatures were obtained in portions of the buildings well above that required to cause fusion.

Dusting of Concrete Floors.

Experiments have been started to determine a suitable material for treating the surface of concrete floors to prevent dusting and increase their durability. This work is part of a more comprehensive investigation which is now being outlined to determine proper methods of construction which will mitigate dusting. An abrasion machine has been designed for testing flooring materials which it is believed will give results comparable with the actual wear on floors, and plans have been made for extensive tests on various flooring materials. Results of this investigation probably will not be available for a year or two.

Investigation of Concrete Aggregate for Panama Canal.

A rather exhaustive series of tests was made of the aggregate at present used in the concrete work on the Panama Canal. Due to a decrease in the demand for material of this character on this project, it was planned to eliminate all but one of the plants producing concrete aggregate, but it was desired to retain that one which produced

the material yielding the most dense and strongest concrete. With this in view several tons of the available aggregates were submitted to the Bureau and tests were made, with the result that it was recommended to employ Ancon crushed stone and screenings. Experiments were also made on concrete containing crushed rock up to 4 inches in size, and it was found that material of this kind increased the amount of inert material that could be added to the same amount of cement without impairing the strength of the resulting concrete.

Development of an 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. A large number of experiments were made and results that are promising have been obtained. It is contemplated to continue the work along the present lines and publish the results in the near future.

Stone Investigation.

In connection with the cooperative investigation of building stones, machinery has been installed for cutting and grinding test pieces, and representative samples of stone have been collected, in cooperation with the Geological Survey and Bureau of Mines, from 80 quarries. Thirty samples of marble and limestone and 86 samples of other stones, totaling 2,784 specimens, have been tested to determine compressive, tensile, transverse strength, on edge and bed, specific gravity, absorption, hardness, staining quality, and resistance to frost action.

A card-index system for filing stone records has been worked up and all available tests made at this Bureau and other laboratories have been collated and filed therein for ready reference. A paper containing the available data will probably be prepared for publication during the ensuing year.

Investigation of Fire Protection for Steel Columns.

The Bureau has cooperated with the Underwriters Laboratories in developing the program of fire tests of various types of steel columns under load. Preliminary designs of protective coverings were prepared and tentative suggestions made as to the concrete and mortar mixtures and materials to be used. Several conferences were held and further assistance rendered in the development of the final program. This investigation contemplates tests of a large number of full-size structural steel columns, protected by commercial coverings such as concrete in various forms, tile, and gypsum. The tests will probably be made during the ensuing year.

Investigation of the Fire-Resisting Qualities of Partition and Supporting Walls.

Designs were completed for the construction of a testing plant including a furnace and 12 panel frames for making fire tests of partition and supporting walls. The frames are heavy steel I-beam and plate sections 17 feet long by 13 feet high and will accommodate

a wall 12 by 16 feet up to 12 inches in thickness. The furnace is designed to have a temperature uniformity within 40° for any two points on the wall for temperatures between 1,400° and 2,500° F. The testing plant will also be provided with fire pump and equipment to give a water stream up to 80 pounds per square inch pressure through a 1⅛-inch nozzle. Most of the equipment has been ordered and part of the construction work completed, but the plant will not be ready for operation until about January, 1916.

The 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 started to determine the suitability of certain tufa rock and volcanic ash, found in that territory, for use as a material to be mixed with Portland cement to produce a cheaper but satisfactory cement for building purposes. The materials have been received and the tests are in progress. It is expected that a report of these tests will be published during the coming year.

Investigation of Integral Waterproofing Compounds.

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 have appreciable value; 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. Plans have also been formulated for the organization of a committee to outline a comprehensive series of tests on the integral method of waterproofing against water pressure. Many inquiries are received on this subject and it is of much concern to all users of cement.

Routine Cement Inspection and Testing.

Cement was inspected during the year at 12 different cement mills located in Virginia, Maryland, Pennsylvania, and New Jersey. The inspection work included the taking of samples, their testing, and subsequent inspection of packing and shipping. A total of 10,125 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 480,808 barrels of cement for shipment to Panama and 207,877 barrels for shipments to Government departments in the United States, for use in the construction of Federal buildings, river and harbor improvements, etc.

Cement was inspected for three companies for the Government of Argentina. This included the sampling and testing of 91 samples, approximately 51,400 barrels. It was necessary that this cement

should pass the United States Government specifications for Portland cement before it could be accepted by the Argentine Republic.

At the Pittsburgh branch laboratory the routine testing of cement for the public has been very slight; but for Government uses it has been so great that it was necessary to place local inspectors at three different plants, who take charge of the sampling and shipping alone, the actual testing being done as usual at the laboratory. It is gratifying to note that the quality as furnished has improved very markedly. Thus, out of 329,000 barrels sampled, it was necessary to reject only 14,600 barrels. During the previous year it was necessary to return to the manufacturer more than twice this amount.

Miscellaneous Investigations and Tests.

A total of 306 samples were tested consisting of sands, screenings, gravels, stones, asbestos roofing boards, sand-lime brick, gypsum, magnesite cements, composition flooring, concrete, cement accelerators, etc.

Twenty-three commercial waterproofing compounds were tested for the Lincoln Memorial and Arlington Memorial to determine their efficiency in preventing moisture and stains from penetrating the pores of marble. Six samples of marble were submitted to abrasion tests to determine the one most suitable for use in the floor of a building which had a floor failure due to severe service. Four commercial types of composition flooring were tested for the United States Marine Corps to determine their suitability under special conditions. Three samples of sandstone were investigated to determine their resistance to fire.

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, the cause of failure of magnesite composition floors, methods of preventing the dusting of cement floors, methods of designing concrete road slabs, suggestions for building code requirements, durability of cement drain tile, the physical properties of marbles, specifications for stucco, fire-resisting properties of structural materials, the corrosion of metal lath, reinforcement of gypsum plasters, 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 stones, the cause of failure of drain tile, the effect of frost action on concrete, suitability of concrete for oil and acid storage tanks, quality of American Portland cements, dampproofing brick and tile walls, dusting of concrete floors, corrosion of metal lath, etc.

From cement manufacturers, architectural stone manufacturers, commercial testing laboratories, requests were received for informa-

tion on the accuracy of sieves, the physical properties of concrete, the value of fine grinding, the value of silica cements, cause of failure of drain tile, the interpretation of cement specification, 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 prepared during the year: Technologic Paper 42, "Standardization of No. 200 Cement Sieves;" Technologic Paper 44, "Investigation of the Durability of Cement Drain Tile in Alkali Soils;" Technologic Paper 47, "The Value of the High-Pressure Steam Test of Portland Cements;" Technologic Paper 48, "An Air Analyzer for Portland Cement;" and Technologic Paper 58, "The Compressive Strength of Portland Cement Mortars and Concretes."

The Purification of Clay.

It has been shown that very small amounts of caustic soda, carbonate of soda, and silicate of soda contained in the water employed in washing clays bring about a sharper separation of the clay and its impurities. The process has been installed in one plant and is being tried out by others. The product thus purified is superior in quality to that obtained by the usual process.

The object of increasing amounts of the same reagents in reducing the quantity of water used in casting slips has been worked out for a number of American clays. A simple efflux tube for determining the fluidity of slips used for casting clay wares has been designed. In this manner the addition of the chemicals can be controlled in factory practice.

The striking effect of sodium-oxalate additions to Florida kaolin in reducing the water content have also been studied.

Porcelain from American Raw Materials.

Experiments conducted both from the laboratory and shop standpoint have demonstrated, first, that the domestic kaolins can be purified so as to result in ware of excellent whiteness and, second, that from American kaolins, ball clays, feldspar, and flint a high grade of chemical porcelain, as well as of hard fire table ware, can be produced. Cooperation was carried on with a number of American pottery plants.

American Raw Materials Replacing the Imported Glass Pot and Crucible Clays.

An exhaustive study of some 15 imported and more than 100 domestic fire clays carried on in cooperation with manufacturers of glass pots has been carried on during the past year. The distinctive properties of the foreign clays were clearly defined and it was sought to replace them by mixtures of American clays. It was shown that while no single American clay found so far possessed all of the qualities of the best European plastic materials satisfactory results can be obtained by the use of a mixture of several domestic clays. The present work demonstrates that the importation of clays for the purposes of the glass and crucible industries is unnecessary, since there

is a considerable number of excellent clays in Missouri, Kentucky, Tennessee, Pennsylvania, New Jersey, and Illinois available for this work.

Mixtures of Easily Vitrifying and Refractory Clays with Reference to their Rate of Vitrification.

In many industrial plants it is necessary to oppose the rapid vitrification of a readily fusible clay or to accelerate it when an inherently more refractory material is used. Work which was done with mixtures of clays representing the opposite types and the extent to which they interact and modify each other was demonstrated.

Vitrification of Clays and Electrical Conductivity.

It has been shown that the softening and partial fusion of clays when being fired is coincident with a marked increase in electrical conductivity.

Softening of Porcelain at Kiln Temperatures.

Previous work along this line has been continued and completed. The specimens which have passed through the often repeated heat treatment are being studied microscopically, since they approach equilibrium conditions very closely. The universal constitution of porcelains will thus become known.

Enamels and Colors.

Owing to the failure of the European supply a number of color and enamel compositions for clay ware and glass have been prepared and placed at the disposal of makers of such material.

Enameled Iron and Steel.

A suitable furnace has been erected and work has been begun on the study of metal enamels with special reference to enamel coating resistant to chemical reagents and to abrasion.

Optical Glass.

This country is entirely dependent on Europe for the supply of glass used in the manufacture of all kinds of optical goods. For this reason the study of the manufacture of optical glass was begun. Suitable furnaces and apparatus were installed. The work is now under way, but no completed results can as yet be reported.

Properties of Halloysite.

A peculiar clay-like mineral occurring in southern Indiana in large quantities, called indianite, a modification of halloysite, was examined with regard to its physical properties and composition. It was found suitable for the manufacture of high-grade refractories and appears to be adapted even to pottery making.

Silica Brick.

The properties of silica brick used in furnaces are being studied with special reference to their permanent expansion and change in crystalline structure.

Testing of Fire Bricks.

In cooperation with the American Gas Institute and the American Refractories Association considerable work has been done in testing the resistance of fire clay products used in gas and coke oven plants to high heats and to loads at furnace temperatures. This information is to be used in working out specifications for refractories used in such important industrial plants.

Hollow Building Tile.

During the past two years a study of the physical properties of tile have been made in cooperation with manufacturers. Numerous experiments have been conducted to find the relative resisting power of different size tiles. The elastic coefficients have been determined in several hundred specimens, chiefly in order to determine the amount of variation that may be expected in the modulus (the ratio of load on tile to its compression under load), this information being desired by engineers in connection with the designing of tile walls and the ultimate loads on different grades and shapes. The relative efficiencies with respect to loading for different arrangement of bracing webs have been determined, and the comparative advantages of laying tile in different position in walls have also been studied. Some experiments were carried out to find the relative stiffness of different walls against lateral pressures, different types of wall construction being used, the walls always being of sizes comparable to those used in practical construction.

Experiments on Strength of Large Brick Piers.

This investigation has been conducted in cooperation with the National Brick Manufacturers' Association to determine the physical properties of large brick piers when under various loadings up to failure. The brick for the piers were selected in such a way as to be representative of the manufacturing output of the important geographical districts east of the Mississippi; these being the eastern district, covering New York and adjacent territory; the Pittsburgh district, covering western Pennsylvania and Ohio; the Chicago and Galesburg districts; and the southern brick manufacturing belt. Vitrified, hard, and common brick were used in the piers and they were laid up in various kinds of mortar, chosen to be representative of engineering and architectural practice. The piers were $2\frac{1}{2}$ feet square and 10 feet high. The elastic constants of the piers were determined and a study made of the causes which most influence failure with respect to the grade of brick, type of mortar, bond, manner of laying the brick, and age of pier, with a view to defining the best load-carrying efficiencies of actual piers used in modern practice. Numerous supplementary tests are being carried out on the individual brick to determine independently their physical properties. These included a series of tests to determine the ratio of the strengths of bricks tested flat to those tested on edge. In this series three grades of bricks were used, one half of these being tested flat, the other half on edge, making a total of 90 individual tests. Thirty of the large piers have already been tested.

Investigation of the Resisting Power of Soils.

A cooperative investigation has been taken up the past year conjointly with the committee of the American Society of Civil Engineers to determine the resisting properties of soils under the various conditions which arise in engineering practice. Numerous factors are presented in connection with the design of foundations and retaining walls, the bearing power of piles, the influence of which properly can usually be determined only experimentally by laboratory methods. Another class of factor arises in connection with the investigation of the laws of flow of plastic materials, as in the case of clay-working plants, or in the phenomena connected with the flow and pressure of grain in elevators. A still further class of phenomena presents itself in connection with the laws of controlling the movement of large masses of earth, as in the case of avalanches, or in the engineering problems of subsidence of earth, the action of freezing in forcing over large walls, etc. The experiments thus far conducted have been largely for the purpose of determining to what extent this branch of investigation will lend itself to laboratory methods, as against the use of statistical methods or judgment applied to field observations, such as has largely been done in the past by many engineers. Various physical coefficients are being found in these connections for different media which simulate actual earths, such, for example, as the density in relation to the pressure, the coefficient of frictions between the earths and bodies "immersed" in them, and the ratio of induced lateral pressure to vertical pressure, with a view to determining what practical range may be expected in these coefficients when the experiments are repeated, either under identical conditions or otherwise. The purpose ultimately is to secure definite data for applying to problems of engineering design after a suitable practical classification of known earths has been determined.

Cooperation with Technical Societies and Institutions.

The Bureau cooperates with technical organizations and educational institutions by contributing papers and articles to their transactions and assisting in giving short industrial courses for the benefit of manufacturers. Very close cooperation is being maintained with the National Brick Manufacturers' Association in the testing of large brick piers, with the American Ceramic Society, the American Society for Testing Materials, the National Paving Brick Manufacturers' Association, and a number of State organizations.

Information as to Clays and Clay Products.

Requests for information come from a large number of present and prospective manufacturers, and in many cases personal visits are made at the laboratories with specimens of raw materials or finished products. This phase of the work is growing more and more in scope and volume. In unusual cases trips have been made to the plants at the expense of the manufacturers.

Clay Testing.

A considerable number of clays have been tested and particular attention was paid to deposits which seemed to be promising raw materials for the pottery and refractory materials industries. Koa-

lins, plastic clays, shales, and surface clays were tested, coming from Florida, Tennessee, North Carolina, Texas, Georgia, Alabama, Missouri, Illinois, Pennsylvania, Maryland, Ohio, Indiana, and other States.

Testing of Clay Products.

Physical tests of fire bricks, building tile, building and paving bricks, and electrical insulators have been made throughout the year in considerable numbers for Government departments, particularly the Panama Canal, as well as for the public at large.

Method of Measuring Plasticity of Lime.

Plasticity is by far the most important property of lime, frequently governing not only the use but also the price of the material. It is therefore extremely important that some method of testing for this property be established. Following the theory for the behavior of plastic bodies under load, a method of test has been developed and a machine designed and built for the purpose. The lime to be tested is mixed with the proper amount of water to form a putty and molded. The mold is immediately removed, and sufficient load is applied to the specimen to cause rupture. The rupture occurs along certain well-defined planes. Measurements of the angle which these planes make with the vertical, and of the load applied, give sufficient data to substitute in Merriman's formulas. The values of the "coefficient of internal friction" and of the "coefficient of cohesion" can now be calculated. The first tells whether the lime is sticky or sandy, the second whether it can be spread out into a thin coat or will tear easily under the trowel. The method has been applied to a large number of samples of hydrated lime, with satisfactory results.

Improvement of Plasticity of Hydrated Lime.

If hydrated lime is mixed with water, the putty formed will not be, in general, so plastic as that made from quick lime. This lack of plasticity is due to the presence in hydrated lime of what is known as "burned hydrate." This material differs physically, chemically, and optically from hydrated lime. The evidence at hand leads to the belief that it is a basic hydrate, which can be formed either during the process of hydration, when the lime may not be given a sufficient amount of water; or, the heat generated may be sufficient to decompose partially the hydrate which has already been formed. Attempts are being made to eliminate the production of this material by changing the design of the machine used for hydration.

Bonding Material in Sand-Lime Brick.

Sand-lime brick consists essentially of sand bound together by a compound of lime and sand which is formed by the action of steam. This compound has been loosely designated as a "hydrated calcium silicate." Since the properties of the brick depend largely on the behavior of the bonding material, it is desirable to know just what this substance is and how it will be affected under different conditions. The material was prepared by mixing pure lime and pure silica in the proper proportions and treating them with steam under high pressure. The resultant product was found to contain one mole-

cule of lime combined with one molecule of silica. There is also some water held in chemical combination, but this seems to vary somewhat with the method of preparation. The silicate is attacked very readily by carbon dioxide, but this action resulted in an increase in the strength of the specimens treated.

Introduction of Carbon Dioxide During the Steam Treatment of Sand-Lime Brick.

In view of the effect of carbon dioxide on calcium metasilicate, it was thought possible to improve the strength of sand-lime brick by introducing carbon dioxide into the cylinder where the bricks are cured with steam. This process was patented, but is not now in use. There seems to be no doubt as to the results obtainable, the question being largely one of overcoming mechanical and economic difficulties.

Method for Estimating the Amount of Free Lime in the Presence of some Silicates and Aluminates.

When examining the calcium silicate found in sand-lime brick, mixtures of lime and silica were treated with steam. It was necessary to determine how much of the lime was left uncombined. The silicate is so readily decomposed that no ordinary method of analysis could be used. The method finally decided upon was to suspend the sample in a mixture of 2 parts of glycerin and 10 parts of alcohol, and titrate the lime with a solution of ammonium acetate in alcohol, using phenolphthalein as an indicator. The method was found to be accurate in the presence of all the compounds which might be present in sand-lime brick. It is accurate in the presence of tricalcium aluminate if especial precautions are taken to eliminate all water. It is not available in the presence of tricalcium silicate.

Information About Lime and Sand-Lime Brick.

The questions asked the Bureau by manufacturers of lime deal mainly with plasticity or with plant equipment. One man wants to know whether his lime is more plastic than another's. One wants to know how to improve the plasticity of his hydrate. Information is desired as to the type of kiln which can be used for burning lime when oil or coke is used for fuel. Consumers desire information mainly in regard to the kind of lime which should be used for a given purpose and where such lime can be obtained. The Bureau is frequently called upon to examine samples of limestone and report on it to prospective purchasers of quarries. Miscellaneous inquiries include the cause of hard lumps or of colored matter in the lime and the availability of oyster shells, marl, or coral as a source of lime.

The National Lime Manufacturers' Association recently established the Hydrated Lime Bureau for the purpose of advancing the interests of hydrated lime. All of their advertising literature is submitted to the Bureau of Standards before publication, in order that no statements will go out to the public which can not be substantiated.

Requests for information relative to sand-lime brick are general in their nature, as, "What is sand-lime brick, and is it safe to use it?" To answer such questions a circular describing the process of manufacture and properties of the material is now in course of preparation.

It is desirable wherever possible to have first-hand information about the condition of the industry and that the manufacturers, dealers, and consumers become personally acquainted with the work of the Bureau. In line with this policy, all of the lime plants now operating in Washington and Oregon were visited. Especial attention was paid to the equipment of the plants, their efficiency and capacity, the quality of lime produced, and the market conditions. It is hoped that the acquaintances formed with manufacturers, dealers, and consumers will result in mutual advantage to them and to the Bureau and that they will feel more inclined to place their problems before the Bureau for solution. Thus the Bureau will be better able to understand their difficulties.

Temperature of Decomposition of Gypsum.

Plaster of Paris, or "hard wall plaster," is an important article in the building trades. It is obtained by the calcination of gypsum. There are, however, other products which can be formed by calcination, and the one which is produced depends mainly on the temperature used. Since these products differ materially in their physical properties, the temperature of calcination is an important commercial factor. A sample of pure gypsum was heated to constant weight at different temperatures, and the material produced was examined. At 110° to 120° C. it lost three-fourths of its water, the product being plaster of Paris. At 140° to 150° C. it lost the rest of the water. The material left was "soluble anhydrite." When mixed with water this material sets as quickly as plaster of Paris and produces a much stronger specimen. If the dry material is exposed to the air, it will quickly absorb water and revert back to plaster of Paris. At about 350° C. soluble anhydrite changes to ordinary anhydrite without any loss of weight. This anhydrite is practically inert to water and will not set in any reasonable length of time.

Effect of Compression in Baling of Raw Cotton.

An investigation has been commenced to determine the effect of compressing raw cotton to densities up to 50 pounds per cubic foot. At the present time American cotton is compressed to densities from 20 to 30 pounds per cubic foot, while cotton put up in Egypt and India is packed to a density of about 40 pounds per cubic foot. If cotton can be compressed at high densities without injury to the fiber, much smaller bales would result. The smaller bales would thus make handling less difficult, reduce the cost of transportation, lessen the cost of covering the cotton, and great saving would result to the railroads, steamship lines, and warehouses. This investigation was urgently requested by the General Managers Cotton Association of the Southeast, and it is hoped that facts will soon be obtained. The results of such an investigation should be very helpful to all that handle raw cotton.

Manufacture of American-Grown Flax.

An investigation was made of linen yarns and fabrics manufactured from domestic flax. Practically all the linen consumed in the United States is imported. One concern situated in the Middle West has attempted to grow flax and manufacture linen materials upon

a commercial scale and to compete with the foreign goods. The Bureau has obtained samples of the domestic product and compared them with similar imported materials. Comparison of the results of physical tests of yarns, household linen, and dress goods showed that the quality of the domestic material was equal to that of the imported.

The results have considerable significance in that under proper supervision flax can be grown in this country to produce fiber which could be utilized in the manufacture of many linens now imported.

Identification of Textile Fibers.

An important investigation has been planned and some work done to determine methods of fiber analysis which will unmistakably identify certain fibers. This investigation will require a careful study, as all the properties of the various fibers used in textile fabrics will probably need to be examined. This study is of growing importance on account of the many new processes to which fibers are now subjected.

Automobile-Tire Fabric Investigations.

The cotton mills manufacturing automobile-tire fabric and the dealers in this cloth have in many instances developed their own methods of tests. The Bureau was urgently requested to develop and to standardize methods for testing this material. In cooperation with several mills the Bureau developed a method for determining tensile strength. This method has been adopted at least for one year by the textile committee of the American Society for Testing Materials. Several members of the society are some of the largest users of tire fabric. Many hundreds of tests have also been made to determine better methods for selecting tensile strength test specimens and for the determination of weight, threads per inch, elongation of fabric, moisture, crimp or yarns, etc. An extensive investigation upon the comparison of various tire fabric tensile-strength testing machines was made during the year. The results were of value in that they showed the inaccuracy of machines in use. One machine was found to record consistently incorrect readings of about 40 pounds, the tests being made upon fabric giving breaking stresses of about 220 pounds.

Adulteration of Textile Materials.

An important field of research is that of ascertaining the extent to which textile materials are adulterated and misrepresented. The public is becoming more and more concerned and often demands a guarantee that the goods purchased are as represented. Many tests by the Bureau during the past year conclusively illustrates the need of an extended investigation. The present work will be continued during the next fiscal year and, if possible, the variety of goods analyzed will be greatly enlarged.

Moisture in Cotton Fiber.

In response to several requests a preliminary investigation was made upon the rate and quantity of moisture cotton fiber would absorb or give up under various atmospheric conditions. A special

instrument was devised and constructed in order to make accurate determinations. The preliminary results indicate that much valuable information should be obtained by the use of this instrument. The work has only recently been undertaken, but will be continued during the coming year. The results of this investigation will contribute toward a better knowledge of the important action of moisture upon textile materials relative to its weigh.

Physical Properties of Spool Thread.

A large number of tests were made upon common spool threads extensively used in the household and by garment manufacturers. Spool threads ranging in size from No. 12 to No. 70 were tested for tensile strength and number. One spool marked "No. 36 and 12,000 yards per spool" actually tested No. 28 and 11,500 yards of thread. It is hoped that an extended investigation upon this subject can be made the coming year.

Tensile Strength and Weight of Fabric as Influenced by its Moisture Content.

The effect of moisture upon the strength and weight of textile fabric has been known in a general way for many years. It is only recently, however, that American manufacturers, buyers, and sellers have realized that they should become definitely acquainted with the moisture content of the fabric they are handling. For instance, automobile-tire fabric (cotton) breaking at 240 pounds, with 3.5 per cent moisture content, will have a tensile strength of 320 pounds, with 8.5 per cent moisture present. Under these conditions of moisture there will be a difference in weight of about 1 ounce per square yard.

Wool fabric is influenced, by the presence of moisture, in the same direction to that of cotton as regards weight, but in the opposite direction relative to tensile strength. In other words, wool fabric will become heavier with additions of moisture but its tensile strength will be less. In view of its importance, future work will cover a wide scope of testing and research.

Worsted Yarn of Commerce.

Wool-yarn manufacturers have requested the Bureau to make a study of the oil and moisture content of the more common worsted yarns. Considerable data have now been compiled, but a much greater variety of yarns will be studied the coming year. Other physical properties, such as tensile strength, correctness of yarn number, and effect of atmospheric moisture will be investigated.

Comparative Tests of Cotton and Wool Flag Bunting.

For many years wool fiber has been employed in the manufacture of bunting in the higher priced flags. During the past year cotton bunting and cotton flags were manufactured at about one-half the price of the wool bunting. A series of comparative tests were made upon several brands of wool bunting and cotton bunting. The tests included tensile strength, weight, fastness of color, and exposure to weather conditions. The cotton bunting was superior to the wool bunting in many respects; therefore cotton is being used rather extensively for many purposes.

The results of tests were furnished to all Government departments, and the Bureau is informed that a considerable saving in many offices has resulted from the use of cotton flags as a substitute for wool.

Scouring of Domestic Wools.

Assistance was given the Division of Animal Husbandry, Department of Agriculture, concerning the shrinkage of certain wool fleeces. These fleeces were carefully grown under the supervision of Government experts with the view to an investigation of the yield of clean wool and a study of the character of the staple. The Bureau scoured 35 fleeces and reported the yield of clean wool. The investigation was done in connection with range breeding experiments that will be continued for some years.

Determination of the Length of Textile Yarns of Commerce.

Considerable study has been made upon methods of accurately determining any length of yarn which has been wound in skeins or upon bobbins, cops, spools, etc. A new apparatus was designed and constructed by the Bureau, and the results of tests thus far indicate that the instrument will be satisfactory. The first importance of this instrument is in determining an accurate length, then by ascertaining the weight of a certain length the size or yarn number can be calculated. The knowledge of the yarn number is of the greatest importance in the manufacture of yarns and fabrics, to the consumer, and in the application of the duty to imported yarns. Under the terms of the last tariff law all imported yarns are taxed at varying rates according to their yarn number. The Bureau has furnished the Customs Service considerable information in designing apparatus and developing better and more economical methods for textile analysis at the various ports. Further researches will be conducted, and it is believed that a method will be developed by which many of the controversies arising in the trade can be readily and satisfactorily settled.

Methods of Testing Twine.

A very important field of work is the drafting of specifications and the testing of twine.

Several of the Government departments combined use more than $300,000 worth of twine a year. The Bureau drafts the specifications for many of these departments, and tests are made upon the deliveries to ascertain if they comply with the requirements. Two thousand and twenty-five balls of twine were tested during the year.

The Post Office Department purchases twine specifying a certain yardage and tensile strength at a definite weight. The Bureau tests the samples under the specified conditions, and it thus enables the price to be satisfactorily adjusted.

Textile Tests.

The materials submitted for examination and the number of samples tested by the Bureau as routine work numbered 3,444, classified as follows: Common twine, 2,023; imported yarn, 860; thread, cord, cable, and rope, 61; denims, tire fabric, bags, sheeting, canvas, blankets, uniform cloth, tracing cloth, coin sacks, flag bunting, book cloth, dress goods, cement bag fabric, shirting, gingham, etc., 500.

More than 300 additional samples were tested in cooperation with mills who assisted the Bureau in some of its investigations. These were not considered as ordinary routine tests.

The samples of material designated above do not properly illustrate the work involved, as the actual number of routine tests were more than 33,000. Samples were submitted by Government establishments and others, and the following number of tests were made: Post Office, 16,752; Customs Service, 8,600; Interior, 3,084; Treasury, 464; Agriculture, 430; Commerce, 130; Panama Canal, 106; War, 150; Mississippi River Commission, 240; private parties, 3,240.

The number of tests increased 33 per cent over the previous year—that is, more than 10,000 tests.

Information Furnished on Textile Subjects.

Many inquiries were received from automobile-tire manufacturers and mills making tire fabric desiring information concerning the testing of the cloth. Several mills sent the Bureau numerous data covering many months of tests, and in return the Bureau rendered assistance in suggesting better methods of compiling these data, methods of tests, and necessary laboratory apparatus and its calibration. The results of the Bureau's investigations were also furnished the mills. The Bureau's activities have led to the adoption by the members of the textile committee of the American Society for Testing Materials of tentative methods for testing and specifications for automobile-tire fabric.

There have been numerous requests by testing laboratories regarding tensile-strength apparatus to install for various textile tests.

From the general public many inquiries were received as to simple methods for determining adulterations, the effect of cotton mixed with wool, employment of artificial silk as a substitute for natural silk, jute as a substitute for flax, hemp, and wool, etc.

From cotton mills information was often requested upon the influence of moisture in the atmosphere when the fiber was passing through certain processes and that of the resultant moisture in the finished product.

The various Government departments were rendered assistance in the drafting of specifications for textile purchases and testing of the deliveries. The latter work was instrumental in the rejection of many deliveries which did not comply with specifications. The work also facilitated the economic purchase of textile supplies. Much cotton bunting and flags are now being used instead of wool, as the Bureau has found that the cheaper cotton material, in many instances, can be economically employed.

The Bureau has assisted manufacturers of special textile apparatus in suggesting improvements on their present machines and desirable new devices needed by the textile industry. It has also constructed machines for the accurate determination of length of textile yarns and the " crimp " of yarns that have been woven into a fabric.

Considerable assistance was given the Customs Service in the proper appraisement of duties upon textile yarns.

Several months of work were devoted in scouring raw wool fleeces for the Agricultural Department. The results of the investigation were valuable to that office in their sheep-breeding experiments.

Special information was given in regard to linen produced from domestic flax.

Publications on Textile Subjects.

The Bureau has recently published a revised edition of Circular No. 41, on "Testing and Properties of Textile Materials." The previous edition of the circular was issued two years ago. It deals in a general way with textile analyses, with particular attention given to methods of test; atmospheric conditions under which certain tests should be performed; precautions to be exercised; results of special tests; adulterated textile materials; rates of charges, etc. Nearly 2,000 copies of the previous issue have been furnished on request to interested parties, and it has been especially in demand during the past year.

Textile schools, manufacturers, buyers and sellers, mill workers, etc., use this circular as a guide in their testing, and it serves in a large way to educate the textile trade along lines of more scientific manufacturing, buying, and selling. This is becoming more and more important for the reason that the large consumers buy upon definite specifications and test all deliveries.

An investigation has been made upon certain characteristics of common cotton yarns with special reference to tensile strength and yarn number under different atmospheric conditions. The results of the investigation have been printed and distributed to the textile trade as Technologic Paper No. 19, "The Physical Properties of Cotton Yarns."

Technologic Paper No. 57, entitled "Difference Between Weight of Raw and Clean Wools," is now ready for distribution. The paper deals with the yield of clean wool obtained after scouring. Tests were made upon 49 fleeces of typical Australian and New Zealand wools commonly imported into this country. The investigation was made to ascertain the shrinkage variation in two samplings of the same fleece and the difference in shrinkage between two fleeces of the same breed of sheep. The results are given in detail and should be of value to wool manufacturers and wool buyers.

The Bureau will forward these papers upon request and will also furnish any other textile information that can be supplied.

Investigation of Paper for Permanent Records.

The statement is often made that for durability no paper made under modern methods can compare with that made 100 or 200 years ago. Undoubtedly many of the modern papers would have a relatively short life as compared with those papers made before the introduction of some of the wood pulps and before the use of chemical bleaching became necessary to satisfy the demand of the public for bright white papers.

The question of the upkeep of modern libraries is a serious one, and at the request of a number of libraries this Bureau is investigating the conditions that cause paper to turn yellow and become brittle. At the present time there are no reliable tests which can furnish information in regard to the possible life of a paper in actual use. The object of this investigation is to develop such tests, in order that permanent papers may be used when needed.

Influence of Atmospheric Moisture on Printing Paper.

Paper used for general printing and for printing by means of the various color processes, such as lithography, etc., are subject to expansion and contraction, due to changes in the amount of moisture in the air. This change in size, if excessive, may cause a serious loss to the printer, due to the spoiling of partly finished work. At the suggestion of a number of lithographers and printers this question has been taken up for the purpose of devising means to overcome this difficulty. There appears to be a point above which a change in the relative humidity (per cent moisture content of the air) will cause a greater change in the dimensions of a sheet of paper than is found to be the case for similar changes in relative humidity below that point. Certain manufacturing conditions tend to increase the effect of atmospheric moisture on the change in size of paper.

It is proposed to study the manufacturing conditions involved, in order to determine means whereby the effects caused by change of humidity may be overcome.

Comparison of Various Types of Paper-Testing Devices.

The necessity for standard methods of testing materials has spread to 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 when used for a particular purpose. With this in view, the Bureau is now carrying out a series of tests on a number of types of testing devices commonly used in the paper industry.

Utilization of Old Papers for Remanufacture into Paper.

One of the most available materials has been very largely overlooked in the demand for a new raw material for the manufacture of paper. Only a small percentage of all paper made is collected for remanufacture. The methods for the recovery of this possible raw material are very wasteful, adding to the cost of the finished product.

It is proposed to study the present methods employed in the recovery of old papers, with the object of determining the most suitable method.

Casein and its Application to the Paper Industry.

Casein is an important substance found in milks. It may be used as an adhesive and as such is very largely used in the paper industry to bind a thin film of clay or other material to the surface of the paper. Paper so treated is known as coated paper, and is used in the reproduction of photographs where detail is essential and for printing by means of the various color processes, such as lithography, etc.

Casein is produced from either skim milk or from buttermilk. Commercial skim milk caseins are superior to buttermilk caseins, due to the fact that they contain less insoluble material, greater adhesive properties, and their use requires a less complicated method. The best caseins are imported, and for this reason any investigation tending to improve the domestic product will help to make an American industry less dependent on foreign made goods.

This casein investigation was undertaken at the request of the Dairy Division, Bureau of Animal Industry, Department of Agriculture, and is a cooperative investigation. The Dairy Division has

installed the necessary apparatus for the manufacture of casein, and the Bureau of Standards has undertaken the study of its application to the paper. Most of the necessary machinery for coating paper has been installed in the paper laboratory, and much of the preliminary work has already been done.

The particular purpose of the investigation is to establish the most suitable methods for the production of skim milk and buttermilk caseins, in order to overcome the great variation in quality found in commercial lots. Attention will be given to methods of testing the finished product and also 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, 3,909 samples; for public and private interests, 157 samples; total number of samples tested, 4,066. The large amount of routine testing is an increase of 36.6 per cent over that done last year and has very seriously handicapped the paper laboratory in carrying out the investigations that have been demanded.

Information Furnished on Paper.

This section has been called upon by the several departments to render special service in connection with the preparation of their paper specifications, and assistance to departmental committees on awards of contracts of this kind has been given to the congressional Joint Commmittee on Printing, General Supply Committee, Post Office Department Supply Committee, Committee on Awards for Government Envelopes, Committee on United States Currency Paper Awards, and a number of other committees.

The range of inquiries has covered not anly the methods and processes used in the pulp and paper industry and the testing of papers but also many inquiries from allied industries. In a number of cases manufacturers have submitted samples of imported papers, with the request that a report be made as to how such papers could be duplicated. Special attention is always given to an inquiry wherein assistance may be rendered to an American industry.

The following is a list of a few of the inquiries received and give an illustration of the range of subjects covered by means of letters and reports:

Report to State of Connecticut as to a suitable paper for their court publications for permanent use.

Reports on the possibility of using certain waste grasses for paper making, it being shown that none of the common grasses are suitable, due to low yield of material, and the cost of manufacture. Such material can only be used when other products of value besides paper pulp are secured.

Requests for standard paper samples and specifications and lists of testing devices and the method of operating the same.

Request for samples of various paper-making fibers and pulps and lists of manufacturers of various pulps and papers.

Suitability of various sizing materials.

Suitability of waste cotton lint from cotton seed for manufacture into paper pulp and guncotton.

The manufacture of vegetable parchment paper and reason why the imported article is of superior quality to that of domestic manufacture.

Details as to the manufacture and use of the following papers: Cigarette paper; dialyzing paper; chemical filter paper; photographic paper; lining paper for electric dry batteries; decalcomania paper, etc.; stereotype matrix paper; lithograph paper; offset paper, etc.

The Bureau has been visited by a great many representatives of the paper trade and has succeeded in establishing cordial relations that will greatly enhance its cooperative work in the paper industry.

Investigation of Lubricating Oils.

As a result of trouble that has been experienced from the emulsification of engine oils in service, the Post Office Department has requested this Bureau to investigate the subject with the view of developing an adequate test for emulsibility. This investigation is well under way, and the apparatus that has been designed for carrying out the work is giving very satisfactory results. A test for emulsibility has been developed, and it has proved of so much value as an aid in selecting the most suitable oil from samples submitted by prospective contractors that it has been added to the list of routine tests to which oils received from Government departments are submitted. In its present form the test does not apply to steam-engine cylinder oils. This test has been communicated to the American Society for Testing Materials for the information of the committee on standard tests for lubricants.

The conversion tables for intercomparison of different measures of viscosity, which were mentioned in the last annual report, have been presented to the American Society for Testing Materials, and will be published in their proceedings as the work of this Bureau.

A publication is in course of preparation in which the theory of viscous flow, upon which the action of viscosimeters depends, will be considered in detail.

Investigation in Connection with Government Power Plants as to Quality of Lubricating Oils.

During the past year the Bureau has employed an oil engineer whose duties are to investigate all complaints of poor service of oils delivered under Governmental contracts in Washington, to ascertain the reasons for unsatisfactory service, and to suggest remedial measures. Numerous visits have been made to Government power plants upon request, and in this way the Bureau has been able to render valuable assistance of a distinctly practical nature.

A large number of oils have been tested, and the General Supply Committee has been advised in regard to revising the forms of contract for the purchase of lubricating oils for Government departments. Specific recommendations have been made, in cooperation with the chemical department, in regard to the comparative value of oils submitted by contractors.

Properties of Rubber.

An investigation of the physical properties of rubber, with special attention to the influence of temperature on these properties, has shown satisfactory progress during the past year. The results of this work appear in the third edition of Circular No. 38, "The Testing of Mechanical Rubber Goods." Practically all of the testing machines and apparatus used in this work have been developed at the Bureau. The Bureau's equipment, which includes a mixing and vulcanizing plant and a testing room with automatic temperature regulation, offers exceptional facilities for research work. A rubber-tubing machine has been installed and is now being used for the production of experimental tubing of various compositions. The object is to develop specifications for laboratory tubing which will insure more satisfactory service than has been obtained in the past. During the past year 34 rubber compounds have been made. About one-half of these have been made into tubing which is being given a service test under varying conditions in the different laboratories of the Bureau. A number of samples of special composition have been prepared and are being used in checking different methods of chemical analysis.

The Bureau has cooperated with manufacturers and technical societies in developing specifications for and methods of testing rubber.

The special apparatus and testing machines designed at the Bureau have been of distinct benefit to the rubber industry and to large purchasers of rubber goods.

Investigation of Rubber Hose.

Specifications for rubber hose often require that the tube or lining be made from calendered sheet. As distinguished from handmade tubes of this kind, tubes are sometimes made by machinery, the process being known as "squirting."

During the past year the Bureau has conducted experiments with the view of developing a test that may be depended upon to identify tubing as "calendered" or "squirted." The investigation has not been completed, but from the results thus far obtained it appears that the elasticity of rubber that has passed through a tubing machine is practically the same in all directions, whereas it is generally known that calendered sheet is more elastic in the transverse than in the longitudinal direction. It is thought that a test for elasticity will prove to be the most satisfactory method of distinguishing between handmade and machine-made tubes in cases where tubes can not be identified by inspection.

Kapok Fiber for Life Preservers.

At the request of the Steamboat-Inspection Service, this Bureau has investigated the value of kapok fiber as a buoyant material for life preservers, and a report based upon the results of chemical, microscopical, and physical tests has been made.

It was found that the buoyant qualities of kapok fiber are not the same for all products of similar trees, and since the difference is purely physical it was recommended that the final valuation of kapok should be on a physical basis. The best test of a life preserver is

a buoyancy test, extending over a definite time, during which time the preserver should be totally submerged at intervals.

Efficiency of Hack-Saw Blades.

Very little progress was made during the past year in the investigation to determine the relative efficiency of hack-saw blades, taken up at the request of the General Supply Committee. The data thus far obtained show that the specifications in general use can not be relied upon to secure blades of good wearing quality and high efficiency. The Bureau's work has shown that in order to compare the results obtained in different laboratories it is not only necessary that the metal used for testing the blades be the same, but that in each case the blades be tested under the same conditions as regards cutting speed, pressure on blade, and length of stroke. The work of this investigation will be continued and pushed as rapidly as circumstances will permit.

Investigation and Tests of Shot Lines for the United States Coast Guard.

Tests of unusual importance have been made in connection with the purchase of flax shot lines for the Coast Guard. The service required of shot lines is of such a nature that it is necessary to exercise the greatest care in selecting the material used in their manufacture and to subject the lines to careful inspection and test. During the past year 160 samples (representing 51,300 yards) of shot lines have been tested, one-half of which was rejected for failure to meet the specified requirements of tensile strength.

Test of Fire Hose for Use in the District of Columbia.

At the request of the District Commissioners, the Bureau has on several occasions during the past year tested 50-foot lengths of fire hose submitted by various manufacturers under competitive bid for acceptance by the District of Columbia Fire Department.

These tests have resulted in a saving of about 50 per cent in the cost of hose without sacrificing anything in quality or efficiency.

Tests of Miscellaneous Materials.

Miscellaneous tests which were made principally for Government departments included 158 samples of rubber hose, 115 samples of packing (rubber, asbestos, etc.), 209 samples of rubber-covered wire, 35 samples of rubber bands, 246 samples of rope, 94 samples of leather belting, 37 samples of hack-saw blades, and smaller numbers of various other materials, amounting to 1,057 samples in all.

III. OFFICE, AND ENGINEERING AND CONSTRUCTION.

1. OFFICE.

Publications.

During the fiscal year just ended the Bureau issued 137 publications, of which 46 were new and the remainder revised editions and reprints. The new publications included five numbers of the Bulletin of the Bureau of Standards, which completes the eleventh volume of the scientific papers. There were also issued 25 scientific papers, 10 new technologic papers, 8 new circulars, and 3 miscellaneous publications.

The following new circulars were issued during the year: "Units of weight and measure, definitions and tables of equivalents," "Standard methods of gas testing," "Safety rules to be observed in the operation and maintenance of electrical equipment and lines," "National standard hose couplings and fittings for public fire service," "Measurement of time and tests of timepieces," "Regulation of electrotyping solutions," "Composition, properties, and testing of printing inks," and "Proposed national electrical safety code."

The following scientific papers were issued: "Testing of potentiometers," "Emissivity of metals and oxides—I, Nickel oxide (NiO) in the range 600° to 1,300° C.," "Adjustments of the Thomson bridge in the measurement of very low resistances," "Quantitative experiments in radiotelegraphic transmission," "Measurements on standards of radiation in absolute value," "Experimental study of the Koepsel permeameter," "Various modifications of bismuth-silver thermopiles having a continuous absorbing surface," "Combustion calorimeter and heats of combustion of cane sugar, benzoic acid, and naphthalene," "Specific heat of copper in the interval 0° to 50° C. with a note on vacuum-jacketed calorimeters," "Equilibrium in the system: lead acetate, lead oxide, and water at 25°," "Watthour meter method of testing instrument transformers," "Insulating properties of solid dielectrics," "Direct-reading instrument for measuring the logarithmic decrement and wave length of electromagnetic waves," "Electrical resistance and critical ranges of pure iron," "Absorption, reflection, and dispersion constants of quartz," "Characteristic equations of tungsten filament lamps and their application in heterochromatic photometry," "Vibration electrometer," "Studies on the silver voltameter," "Wheatstone bridge for resistance thermometry," "Emissivity of metals and oxides—II, Measurements with the micropyrometer," "Emissivity of metals and oxides—III, Total emissivity of platinum and the relation between total emissivity and resistivity," "Comparison of stellar radiometers and radiometric measurements on 110 stars," "Temperature coefficient of magnetic permeability within the working range," "Methods of measuring the inductances of low-resistance standards," and "Emissivity of metals and oxides—IV, Iron oxide."

The following technologic papers were issued: "Industrial gas calorimetry," "Iodine number of linseed and petroleum oils," "Observations on finishing temperatures and properties of rails," "Analysis of printing inks," "Veritas firing rings," "Lead acetate test for hydrogen sulphide in gas," "Standardization of No. 200 cement sieves," "Hydration of portland cement," "Study of the Atterberg plasticity method," and "Study of some recent methods for the determination of total sulphur in rubber."

The following miscellaneous publications were issued: "Annual report of the Director for the fiscal year ended June 30. 1914," "Ninth annual conference on the weights and measures of the United States," and "Decennial index to the Bulletin of the Bureau of Standards."

Technical Library.

The Library contains 12,800 accessioned volumes, almost all of a scientific and technical character, being an increase of 1,125 for the fiscal year; and 362 periodicals are currently received, 211 in English and 151 in other languages.

Personnel.

During the year the Bureau staff comprised 233 statutory appointees, and about 150 engaged in researches and investigations specially authorized by Congress. The statutory positions included 145 scientific positions, 32 office assistants, 34 engaged in the operation of the plant, and 22 in the construction. There were 323 personnel changes during the year. These included 65 separations from the Bureau, of which 34 were resignations.

Correspondence.

The Bureau's correspondence is mainly technical and scientific in character and requires the attention of experts and special care in the preparation of replies. The problem of indexes and files is necessarily complex in view of the wide range of technical subjects covered by the Bureau's functions. The number of letters handled by the file room during the fiscal year was 65,000, an increase of about 20 per cent compared with the previous year. In view of lack of space and help the system of indexes and files was reduced to a minimum several years ago. Experience has shown that undue simplicity as recommended by some filing experts may easily reduce the efficiency in view of Government requirements. It is felt that the growth of the correspondence requires that the system be revised and a more complete cross-reference and charging system be installed. This is now under consideration and will be arranged as soon as possible.

Storeroom.

The purchase and distribution of equipment and supplies is handled through the storeroom. This includes system for orders, inventory, charging out, and stock catalogue and maintenance of standard supplies. The inventory record covers more than 60,000 pieces of equipment, largely scientific apparatus of the most varied kinds. It has become necessary that a high-grade clerk be provided as a property clerk.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1915, 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, 1915:

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$293,500.00	$266,412.79	$12,020.37	$15,066.84
Equipment	[a] 57,311.33	38,184.85	19,091.96	34.52
Repairs and alterations	2,000.00	1,524.02	474.50	1.48
General expenses	27,000.00	21,584.35	5,320.39	95.26
Grounds	6,000.00	5,001.67	997.07	1.26
Testing structural materials	100,000.00	85,940.45	13,970.47	89.08
Testing machines	30,000.00	28,313.20	1,647.45	39.35
High potentials	15,000.00	13,229.81	1,766.75	3.44
Refrigeration constants	15,000.00	13,996.45	995.03	8.52
Testing railroad scales	40,000.00	17,629.54	22,370.46	.....
Fire-resisting properties	25,000.00	15,668.85	9,308.51	22.64
Testing miscellaneous materials	20,000.00	18,704.61	1,217.96	77.43
Railway materials	15,000.00	10,442.95	4,548.49	8.56
Public utility standards	25,000.00	16,528.01	8,317.16	154.83
Chemical laboratory	25,000.00	2,375.00	3,532.30	19,092.70
Total	695,811.33	555,536.55	105,578.87	34,695.91

[a] Includes reimbursement of $7,311.33.

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1915:

FISCAL YEAR 1913.

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$241,312.66	$226,682.95		$14,629.71
Equipment	50,000.00	49,054.36	$619.20	326.44
Repairs and alterations	2,000.00	1,980.80		19.20
General expenses	25,000.00	24,544.05	174.18	281.77
Grounds	3,000.00	2,986.81		13.19
Testing structural materials	[a] 77,342.50	77,045.29	47.99	249.22
Testing machines	30,000.00	29,841.13		158.87
Investigating effects of electric currents	10,000.00	9,921.03	4.50	74.47
Refrigeration constants	15,000.00	14,915.58	45.10	39.32
Additional land	85,000.00	68,034.00		16,966.00
Tank	5,000.00	4,996.98		3.02
Total	543,655.16	510,002.98	890.97	32,761.21

FISCAL YEAR 1914.

Salaries	$290,940.00	$270,123.88		$20,816.12
Equipment	[b] 59,075.00	58,417.49	$540.18	117.33
Repairs and alterations	2,000.00	2,000.00		
General expenses	27,000.00	25,365.14	467.13	1,167.73
Grounds	3,000.00	2,997.53		2.47
Testing structural materials	75,000.00	74,609.04	136.89	254.07
Testing machines	30,000.00	29,924.67	42.66	32.67
High potentials	15,000.00	14,963.71	4.10	32.19
Refrigeration constants	15,000.00	14,601.61	348.48	49.91
Testing railroad scales	25,000.00	22,315.06	2,684.94	
Fire-resisting properties	25,000.00	23,324.49	856.04	819.47
Equipment, electrical laboratory	25,000.00	24,960.66	22.30	17.04
Workshop and storehouse	45,000.00	44,536.22	423.78	40.00
Total	637,015.00	608,139.50	5,526.50	23,349.00

[a] Includes reimbursement of $2,342.50.
[b] Includes reimbursement of $9,075.

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 1915 the Bureau made 116,204 tests and inspected 1,861,439 incandescent lamps at various factories for other departments of the Government. Of the total tests, 105,992 were for the Government and 10,212 for the public. The testing was distributed as follows, according to nature of tests: Length measures, 949; mass, 7,529; capacity, 2,230; temperature, 15,734; hydrometry, 2,224; miscellaneous, 153; optical, 1,500; time, 28; electrical, 1,223; photometry, 3,506; chemical, 11,471; engineering (miscellaneous), 878; engineering (instruments), 367; structural materials, 60,989; paper and textiles, 7,359; metallurgical, 64. The estimated fees amount to $154,733.59, of which $14,438.43 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, 1915.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length	636	$1,025.30	313	$830.50	949	$1,855.80
Mass	6,252	3,293.45	1,277	657.65	7,529	3,951.10
Capacity	1,803	530.15	427	331.35	2,230	861.50
Optical	1,443	1,709.70	57	92.50	1,500	1,802.20
Hydrometry	2,066	2,081.50	158	273.00	2,224	2,354.50
Miscellaneous	144	190.40	9	13.80	153	204.20
Time			28	120.00	28	120.00
Temperature	9,843	3,588.39	5,891	2,979.04	15,734	6,567.43
Electrical	770	2,675.00	453	2,988.00	1,223	5,663.00
Photometry [a]	3,330	11,483.55	176	629.30	3,506	12,112.85
Chemical [b]	10,856	66,878.10	615	3,164.40	11,471	70,042.50
Physical and mechanical tests:						
Engineering, miscellaneous	878	2,520.50			878	2,520.50
Engineering instruments	314	1,589.00	53	229.50	367	1,818.50
Structural materials [c]	60,634	32,531.67	355	1,374.00	60,989	33,905.67
Paper and textiles	6,982	9,741.45	377	598.51	7,359	10,339.96
Metallurgical	41	457.00	23	156.88	64	613.88
Total	105,992	140,295.16	10,212	14,438.43	116,204	154,733.59

[a] In addition, the Bureau inspected 1,861,439 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $5,546.47 additional.
[b] Of these tests, 5,513, amounting to $39,941.80, were chemical tests made on structural materials.
[c] These figures include the inspection of approximately 53,708 samples of Portland cement.

2. ENGINEERING AND CONSTRUCTION.

Mechanical Plant.

The completion of the chemical laboratory authorized by Congress will necessitate enlargement and remodeling of the power and heating system by the construction of an addition to the present building, or a smaller one detached from it, to provide for additional boiler and power-plant space. The Bureau has also outgrown the capacity of its refrigerating plant originally installed at the establishment of the Bureau. The necessity for the control of temperature and humidity in many tests and experimental problems requires the installation of a larger plant at the earliest possible moment. The general condition of the power plant is far too inadequate.

Construction Facilities.

The care of the mechanical plant, of the buildings, and especially the construction of special apparatus of all kinds, necessitates a corps of mechanics skilled in the various kinds of construction. Every investigation requires the construction of more or less special apparatus involving mechanics skilled in the construction of all kinds of precision instruments. These services include plumbing and steam fitting, electrical wiring, woodworking, instrument making, glass blowing, and glass grinding—all are involved in both investigational and testing work. In fact the Bureau's efficiency depends very largely upon having services of this sort available.

Care of Buildings and Grounds.

The care of the buildings of the Bureau has been inadequate for several years. This has been in part remedied by a system of continuous supervision of the janitor service. It is hoped that the janitor service may be increased during the coming year.

During the year some grading has been completed south of the main laboratory and around the east laboratory. Pierce Mill Road has been temporarily improved by eliminating bad curves and extreme grades. This has resulted in improved truck service. The care of the grounds has become of sufficient importance to warrant the continuous employment of a foreman.

IV. RECOMMENDATIONS.

Buildings.

Attention is again called to the necessity of properly housing the structural materials work, especially the branch of the work at Pittsburgh, and which is temporarily located in buildings of the War Department at the Arsenal grounds. These buildings are entirely unsuited for the purpose either as to location or character, and the Bureau has considered it unwise to expend any funds on their preparation as laboratories other than the barest necessities. Furthermore, the War Department has repeatedly asked for the vacation of the building.

Every effort is being made by the Bureau to place its structural work on a basis commensurate with its importance. Considerable heavy equipment has been accumulated both at Pittsburgh and Washington, and more will be needed. Good work is being carried on at both places but the large testing machines, furnaces, and other heavy equipment should be brought together in a building designed for the purpose and sufficiently large to accommodate all heavy equipment of this kind. It is uneconomical and inadvisable to proceed with the installation of permanent heavy equipment in temporary quarters.

Transverse Testing Machine.

Attention is again called to the necessity of adding to the Bureau's equipment a large transverse testing machine capable of testing the transverse strength of full-sized steel girders used in bridges and buildings; also brick, stone, and concrete arches, floor constructions, etc.

Since transmitting the original estimate for this machine, much additional evidence has been secured, all indicating the great need on the part of engineers for data that can only be obtained by a large machine of this character. It is therefore recommended that a sufficient sum be again included in the estimates to enable the Bureau of Standards to begin its design and construction.

Radio Laboratory.

Radio communication has recently become of extreme importance both in Government work and to the public. This method of communication is still largely in the experimental stages. Future progress and improvement in radio communication will be in direct proportion to the progress that is made in the knowledge of the underlying principles involved. Several departments of the Government are deeply interested in maintaining this method of communication on the best possible basis. It would not only be more economical, but productive of much more efficient work to concentrate the laboratory

work of the Government at one place in a small laboratory especially designed for it. It has been agreed by all of the departments concerned, namely, War, Navy, Treasury, Post Office, Agriculture, and Commerce, that the location of the laboratory at the Bureau of Standards would prove of great benefit both as to the economical performance of the work and by its close proximity to the scientific work of the Bureau, especially that of the electrical division. An item of $50,000 for the construction of a suitable radio laboratory was included in the estimate for the current year, but was not appropriated for. It is recommended that it be again submitted in the estimate for the next fiscal year.

Salaries and Additional Assistance.

Moderate increases are submitted for the heads of divisions. These positions involve the responsible administration of the several lines of the Bureau's technical activities. The compensation is not adequate either in view of the duties involved, the order of ability required, or in comparison with similar grades elsewhere. These include the chief physicist, chief chemist, the physicists, secretary, and chief mechanician.

Several increases are also submitted for the skilled workers in the operative and construction staff, namely, the glassworker, the glass blower, and the skilled woodworker. An increase in these salaries is desirable, as their rate of pay is below the average standard for such services elsewhere. An estimate is also submitted for an increase for the assistant engineer, who is in direct charge of the engineering plant and the systems of heat, light, and ventilation connected therewith.

During the past two years the Bureau's work has grown far more rapidly than its resources. This is especially true in consultation and testing work for the Government. In several sections of the Bureau it has been necessary to suspend all investigations in order to care for the testing of materials purchased on Government contracts. This would not be so serious if suitable specifications and methods of testing were in existence for the wide range of materials to be tested; but it can truly be said that such is the case in only a very limited number of materials. It is felt that this situation can be remedied to a large extent by a reasonable increase in the minor assistants, such as apprentices, aids, and assistants up to and including the grade of $1,400. A few of these men in each section could almost double the Bureau's output of testing, and, what is still more important, allow more time on the part of advanced men for the improvement of methods and specifications.

Clerical Services.

The clerical assistance of the Bureau has been entirely inadequate for the past four years. So critical has this become during the past year that it is a serious question as to whether the Bureau is not very materially reducing the efficiency of all branches of its work by the lack of anything like adequate clerical assistance. This is especially true in the case of property records, accounting, files, and correspondence.

Skilled and Unskilled Labor.

The situation of the Bureau is such that it is impractical to secure economical contracts for small jobs of construction. These are continually arising in all kinds of experimental work. Their nature is such that they require the supervision of the experts of the Bureau. It is no uncommon matter when soliciting bids for this class of work to receive them of three or four times the amount necessary. This is due to the distance of the Bureau from the city, the necessity for the supervision of the work on the part of the contractor, and his hesitation to undertake work of a character unfamiliar to him. It is therefore recommended that the Bureau staff of this class of skilled and unskilled laborers be increased.

Technical Investigations.

Items are included among the estimates for the fiscal year 1917 to cover several of the more urgent technical and scientific investigations which should be undertaken by the Bureau. There is the utmost need in the industries for accurate data concerning materials and energy, their measurement and properties. These subjects are a part of the authorized functions of the Bureau, but they have not yet been adequately provided for. These appropriations will enable the Bureau to render a direct service to the industries concerned. The investigations include color standards, clay products, standard materials, physical constants, standardization of mechanical appliances, and textiles, paper, leather, and rubber.

The economic value of these investigations will unquestionably repay many times the original outlay. That they are urgently demanded by the industries is evidenced by the continual receipt of letters calling for the data which these investigations alone can supply. Furthermore, the results will enable the Bureau to put the work of standardizing the measurements and quality of these materials upon a basis not heretofore practicable.

Promotion of Export Trade.

It is intended to use this appropriation to meet a new and urgent demand which has recently arisen from several industries for the certification of American products for export trade. In the trade-promotion work of this department it is found that a governmental certificate of the actual quality of export products is becoming more and more necessary. In many foreign countries the government testing laboratories are furnishing such certifications, and this gives the foreign manufacturer a distinct advantage over the manufacturer in this country, especially in cases where a quality certification by a recognized governmental agency is required by the specifications for the materials to be exported. This appropriation is designed to place the American exporter, so far as possible, on an equality in this respect with his foreign competitors.

The appropriation provides for the charge of an adequate fee for each certification to be made by the Bureau of Standards to reimburse for the expense incurred.

The appropriation suggested will prove a great help to manufacturers and producers in this country who are desirous of selling their goods to foreign countries.

Respectfully,

S. W. STRATTON, *Director.*

To Hon. WILLIAM C. REDFIELD,
Secretary of Commerce.

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