ANNUAL REPORT

OF THE

DIRECTOR
BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1914

WASHINGTON
GOVERNMENT PRINTING OFFICE
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REPORT

OF THE

DIRECTOR, BUREAU OF STANDARDS

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 1, 1914.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1914.

I. FUNCTIONS, ORGANIZATION, AND LOCATION.

Since the Bureau of Standards deals almost entirely with scientific and technical problems, the following brief statement as to its functions and organization may be of assistance to those who are more or less unfamiliar with its work.

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

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 even more difficulties than 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, but 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 thou-

sands 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, or engineering structure.

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 others than those engaged in the scientific and 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 chemical properties or the particular combination of elements which make it of good or poor quality; how are its properties to be measured or its con-

stituents 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 and 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 manufactures 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 guarantees 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.

Government purchases are not greatly different from those of the public. Whenever the Bureau makes a scientific investigation or secures information from other sources for the purpose of the improvement of specifications used in connection with Government purchases, whether for measuring instruments or for materials or equipment, such information or data is given to the public in the form of suitable publications. The value of this information from the standpoint of the public is even greater than that in connection with Government purchases, important as the latter is. In other words, the needs of the public and the Government service are precisely the same as far as standards or specifications are concerned, whether it be standards of measurement, quality, or performance.

In the case of the public, the Bureau confines its work to those investigations, experimental or otherwise, which enable it to give intelligent advice regarding the use, purchase, and testing of the more important apparatus and materials, leaving the testing to commercial laboratories; except, of course, in the case of standards of measurement, where it is absolutely essential that the standards of the public be compared with those of the Government to secure uniformity of measurement, and in unusual cases of testing where the public is not yet provided with suitable means or equipment. In the case of the Government, the Bureau goes further and serves as a testing Bureau for the various departments 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 most people suppose. The Government can do no greater service to the country than to place its own purchases on a basis which may be taken as a standard by the public at large.

5. 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, 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 Agricultural Department 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.

6. ORGANIZATION.

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

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

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

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

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

In the case of the more important technical fields, divisions have been formed dealing more specifically with large and important classes of materials, but many of the purely scientific questions involved would be handled by one of the above 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 the above 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 most 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.

7. LOCATION.

The laboratories of the Bureau of Standards are located in the northwest section of Washington, on Pierce Mill Road, near Connecticut Avenue, and are reached by the Chevy Chase car line. 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 investigation, has been greatly increased by the location of the laboratories in a section free from the ordinary disturbances of city life.

II. SCIENTIFIC AND TECHNICAL DIVISIONS.

1. WEIGHTS AND MEASURES.

Weights.

During the year 16 States have had standard weights tested. In some cases the weights submitted for test were new and of modern manufacture and design, and in others they were very old and were either tested for temporary use or discarded. The number of States submitting standards for test and the character of the standards indicate the increased interest that is being taken by the public in weights and measures work. The Bureau has tested for the Post Office Department 80 sets of test weights, which are to be shipped from place to place by that department for use in verifying scales in use in its dealings with the public. The necessity and the desirability of the Government maintaining accurate scales of highest standard in its transactions with the public has been pointed out on various occasions by this Bureau.

Cast-iron weights, under investigation for several years, have shown conclusively that such weights must be checked at least once a year to insure their accuracy, even when not in use.

Improvement in the design of what are commonly called test weights has received a great deal of attention by this Bureau, and manufacturers, following the suggestions of the Bureau, are now producing reliable weights of this kind. Further efforts are being directed toward reducing the cost of these weights, since large numbers of them are used by local sealers of weights and measures.

Improved facilities for work of the highest precision were secured at the close of the year by the construction of a double walled constant temperature room, which is divided into separate compartments for the balances and the operator. The work of fitting up this room will be carried on as rapidly as the routine work will permit.

Capacity Measures.

The number of capacity measures tested during the past year amounts to 295, as compared with 66 the previous year, there being a large increase in the number submitted by the United States Government and State institutions, as well as by private parties. There has also been a large increase in the number of cubic-foot bottles or fractional cubic-foot bottles submitted for test for use as standards in the testing of gas meters.

With the enlargement of the division's quarters, made possible by the removal of the electrical division to the new east laboratory, more space has been allotted to the work of testing capacity measures, resulting in the work being handled much more satisfactorily.

There was a considerable decrease in the number of length measures submitted for test, due to a great extent to a less number being presented by the Government. A 100-foot bench standard, located in the City Hall, Chicago, was graduated and standardized for the Western Society of Engineers.

The Bureau has cooperated with the manufacturers' standardization committee with a view to securing greater uniformity in the use of the American Briggs pipe thread standards, and it is expected

that a set of standards on this system will be deposited with the Bureau.

Inspection of Scales.

One man has been detailed at Chicago during the entire year to inspect scales being manufactured for the Post Office Department. Two thousand one hundred and thirty-two scales have also been tested for the Post Office Department at a factory in Vermont. The advisability of having scales purchased by the Government thoroughly inspected and tested before being accepted, and of having this work done at the factory, as recommended by the Bureau on previous occasions, has been fully demonstrated by the scale inspections at the factory.

In addition, the Bureau has received many requests from the Navy Department and other departments to test scales, but all of these requests could not be complied with on account of lack of sufficient force and equipment. The same was true in several instances where tests were desired by corporations or individuals in States where such work has not yet been taken up by State or local authorities. In some of these latter instances it was clear from the correspondence that the results obtained from the use of the scales in question were of vital importance to the communities or individuals concerned.

Cement Sieve Testing.

The methods of testing the sieves used in the testing of cement has been well systematized so that this is now quite a routine matter. As a result there has been a great improvement in the quality of the sieves submitted for test and the percentage of rejections has been greatly reduced.

Time.

Early in the year a room for the testing of watches was prepared, and was equipped with heating and cooling apparatus, fans for the circulation of the air, thermostat and automatic switch for controlling the temperature. Proposed regulations for the testing of watches were drawn up and submitted to the various jeweler's journals and to manufacturers of watches, together with a statement of the preliminary tests that had been made at the Bureau, and its plans for the future testing of watches for criticism. A conference of watch manufacturers was held at this Bureau in February, at which these regulations were discussed. Practically no change in the regulations was made by this conference, and the regulations were put into effect by the Bureau. The first watch test was made in April, and the Bureau is now prepared to hold these tests regularly four times a year. It is confined to the higher grades of watches only, for which a fee is charged.

Gas-Meter Testing.

The investigation of various methods and devices for measuring gas during the past year has been developed with considerable satisfaction. The use of oil instead of water in cubic-foot bottles has been under trial for several months and promises to be an improvement over the usual method. A method of testing laboratory gas

meters has been devised which has a number of advantages over that now in use. An investigation of the factors affecting the accuracy of laboratory wet-gas meters is in progress. An improvement in meter provers to minimize errors in testing dry-gas meters, and other apparatus, is being developed. An extensive investigation of the closeness with which the discharge of acetylene burners of various manufacture occur was made and some valuable and interesting results were obtained. During the year a few laboratory gas meters for laboratories outside of the Bureau were tested, and also a number of meters of the same type for various kinds of Bureau work involving the measurement of gas.

Volumetric Glassware.

The routine testing of volumetric apparatus to be used as standards and for precision work in chemical laboratories and by the Government included flasks, cylindrical graduates, burettes, and pipettes. During the year this testing comprised 3,344 pieces of apparatus; and 1,213 hydrometers, principally for the Internal-Revenue Service in connection with the collection of revenue on distilled spirits, were examined. In addition to these tests 109 density determinations have been made. Aside from the routine work just mentioned, a large amount of research has been carried on by the volumetric section with a view to the improvement of the design, testing, and use of volumetric standards.

An investigation of the density and thermal expansion of milk and cream has been made for the dairy division of the Department of Agriculture, and a similar investigation of linseed oil and turpentine was completed for the American Society for Testing Materials. This last work was a continuation of and supplementary to the work done for the society three years ago. During the year work on the expansion of petroleum oils has been continued and a very considerable amount of data is now available. It is expected that during the coming year the work will be completed and tables prepared for the use of oil inspectors and others who may have occasion to use information on the rate of change of density and volume of oil with change of temperature.

Expansion of Materials.

An investigation of the expansion of a bronze bar due to changes in temperature has been carried on for some months. This property of the bronze bar in question was first investigated in an oil bath in temperatures ranging from 20 to 150° C.; subsequently an electrical furnace was employed between the temperatures of 17 and 630° C.; and later a third series of observations between 14 and 300° C. were made with a new dilatometer and oil bath. The results of these investigations showed, first, the precision of the method with three different pieces of apparatus; second, the regularity with which the bronze assumed a definite length at a definite temperature; third, indications of structural rearrangements too small to be detected by the ordinary cooling-curve method of thermal analysis; and fourth, the possibility of maintaining the material while being heated (under certain conditions) in an unstable state and in which it expands much less than ordinarily.

The thermal expansion of samples of glass, porcelain, and brass have also been investigated.

An investigation has been commenced to determine whether any relation exists between the thermal expansions of a metal and the simultaneous changes in its electrical resistance. This was undertaken partly for the purpose of determining, if possible, a method of checking one class of measurements by means of the other, and partly to accumulate data that might have other practical as well as theoretical application. The results already obtained show that, in at least some cases, readjustments of internal structures that are accompanied by minute increments of length are also accompanied by corresponding increments of electrical resistance.

Barometry.

Investigations of mercurial and aneroid barometers have been carried on during the year and problems of practical application have been studied and experimented upon. A standard method has been adopted for the testing and certification of high-grade aneroids. This test emphasizes the discrepancies between the results obtained with pressure changing rapidly, as compared with slow changes; also that the instrument should be free from various mechanical errors frequently met, and that it should include a simple temperature test. Besides the standard method, a short method of testing has been adopted for low-grade aneroids and a definite method is about to be adopted for testing short-range aneroids used in navigation and in the household.

During the year two representative aneroids taken abroad in the summer of 1913 were tested at the national standardizing laboratories of Germany, England, and France. The reports have been analyzed and the data are most interesting and leave no doubt as to the superiority of our own method.

In the past year an improved method of setting a mercury surface to a required height has been devised, by means of which the accuracy of certain types of barometers and other pressure gauges involving the use of mercury, may be increased.

Track Scale Testing Equipment.

The railroad track scale testing equipment of the Bureau, secured under an appropriation of $25,000, available July 1, 1913, was completed and ready for service in September. During the year tests were made on 38 railroad scales in Connecticut, Vermont, New York, and New Jersey. The tests made in the two latter States were for the Customs Service in the vicinity of the Port of New York.

Aside from the value of these tests as indicating the accuracy of the scales examined, they yielded much data which will be of value in determining the best methods of testing such scales and improving the design, with a view to obtaining greater accuracy and reliability.

Allowing a tolerance of 0.2 of 1 per cent, which, in the opinion of the Bureau, is a fair tolerance for such scales, 80 per cent of the 16 scales tested in Vermont would have been rejected; on a tolerance of 0.4 of 1 per cent 60 per cent would have been rejected; and on a tolerance of 1 per cent 40 per cent would have been rejected. The magnitude of some of the errors was as follows: 1,349 pounds with a

load of 35,000; and 1,149, 1,129, and 2,459 pounds on three scales with loads of 70,000 pounds. Of the 16 scales tested at the Port of New York, 75 per cent would have been rejected on a tolerance of 0.2 of 1 per cent, 56 per cent on a tolerance of 0.4 of 1 per cent, and 25 per cent on a tolerance of 1 per cent.

The above results clearly show the necessity for periodic inspection of such scales and indicate to some extent the great losses which may be sustained by the use of uninspected track scales. As previously pointed out, the inspection of railroad track and elevator scales should be taken up by or under the supervision of the Federal Government, rather than by the States, for the reason that practically all shipments weighed upon them are interstate.

Requests for services of the car have been received from State and city officials and others in a number of States, among which may be mentioned Ohio, Indiana, Illinois, Missouri, Iowa, Minnesota, Wisconsin, and Tennessee, and, no doubt, many other requests will be filed from time to time. It is obvious that one, or even two, cars could not comply with all these requests within a reasonable time, to say nothing of many other scales in every State in the Union which should be inspected. While another car will be procured under the appropriation of $40,000, available July 1, 1914, it is evident that additional cars will be required in the future for this work.

It is respectfully recommended that Congress be urgently asked to increase the sum available for the investigation and testing of railroad track scales, elevator scales, and scales purchased by or belonging to the Federal Government, and also to provide facilities for cooperating with States in their endeavor to bring about uniformity in weights and measures.

With the $40,000 made available July 1, 1914, an additional test car of 75 tons capacity will be provided and also a master scale on which the 10,000-pound weights used in this work may be compared. These two items with the additional help needed in this work and the expense of keeping two cars in the field will consume the amount provided. The numerous demands for the car now available clearly demonstrate that if the Bureau is in any way to adequately occupy this field it should have additional cars with the necessary equipment and crews to operate them.

Assistance to Porto Rico.

At the request of the Bureau of Insular Affairs this Bureau detailed one of its experts, to organize an inspection department of weights and measures for the island of Porto Rico, under an act of August 18, 1913, requiring the inspection of all commercial weights and measures in use under the supervision of the Secretary of Porto Rico.

It devolved upon the Bureau's representative to devise a system of keeping records suitable for the service, to advise what kind and quality of apparatus should be obtained for primary standards and for the use of the inspectors. Keeping in view the amount of the appropriation available, the needs of the service, and the climatic conditions; to make rules and regulations for the enforcement and clearer understanding of the law, as provided by section 10 of the act; to write explicit instructions and devise tolerances and specifica-

tions for the guidance of the inspectors; and, finally, to instruct them in the duties of their office.

Thus, there was established at the beginning a complete record system, and an organized force of inspectors, equipped with suitable apparatus and provided with specifications and tolerances for the inspection or rejection of apparatus, the entire organization and its management being based on years of experience, and having at the outset a degree of perfection such as has not been obtained by States of the Union after years of experience.

Too much emphasis can not be laid upon the importance of properly establishing an inspection department at the outset and avoiding methods of inspection and administration which are at once inimical to the best interests of the consumer and detrimental to the merchants. By properly establishing a weights and measures department at the beginning, results favorable to the consumer, as well as to the honest merchant, immediately accrue, and all prejudice against weights and measures inspection is thus forestalled.

In this connection attention is called to the fact that opportunities for rendering similar services to States in the Union are continually arising, and it is to be regretted that the funds, as well as the force, available for such work, are entirely inadequate to meet the needs.

Weights and Measures Conference.

The Ninth Annual Conference on Weights and Measures was held at the Bureau of Standards in May of this year, and was more largely attended than any previous meeting, there being representatives from 26 States and the District of Columbia and 67 cities and counties; in all, 116 officials. There was also present a large number of manufacturers and other persons interested in the subject of weights and measures. In addition to an excellent program, an interesting and instructive feature of the meeting was the exhibit by manufacturers of various types of weighing and measuring apparatus.

The wisdom of these conferences being fostered by the Bureau is demonstrated each year by the fact that increased interest is taken in them because of their association with a Federal bureau; by the cooperative work accomplished tending toward uniformity in the weights and measures legislation passed by the various States; and in the tolerances and specifications for commercial apparatus adopted by a number of the States. These conferences not only bring the State and city officials in contact with the Bureau, but are of great assistance to officials from States and communities newly organizing weights and measures service.

Legislation.

An act of Congress, important in the field of weights and measures and one which has received a great deal of attention by this division, was approved March 3, 1913, making amendment to the food and drugs act of June 30, 1906, which requires that the net weight, measure, or numerical count shall be plainly and conspicuously marked on the outside of all packages containing food. Legislation of this character has been long sought by friends of honest weights and measures, and success has finally been attained largely through fear on the part of the opposition that the action of a few

States in passing legislation of this kind would be followed by many other States, and thus manufacturers of products for interstate shipment would be obliged to comply with many laws having different requirements and conflicting provisions.

In connection with this amendment the chief of the weights and measures division of the Bureau represented the Secretary of Commerce on a committee of three, representing the Secretaries of Commerce, the Treasury, and Agriculture, appointed to draft rules and regulations for the enforcement of this amendment.

Two weights and measures bills of importance are now pending before Congress—one "to fix a standard barrel for fruit, vegetables, and other dry commodities," and the other "to regulate and control the manufacture, sale, and use of weights and measures." This latter bill provides that the Bureau of Standards shall have the authority to approve and shall approve the various types of weighing and measuring devices which may lawfully be used in trade and commerce throughout the United States. The principles involved in each of these bills have the hearty indorsement of the Bureau, and it is hoped that the pending legislation will soon be enacted.

The division has also been keeping informed as to weights and measures legislation passed by the States, obtaining carefully verified copies, so that the Bureau's publication of State and national laws "Concerning the Weights and Measures of the United States" may be revised promptly when deemed advisable, and in order that correspondence may be more expeditiously and satisfactorily answered than would be possible without having such legislation at hand.

Publications.

During the year there have been issued "The report of the eighth annual conference on weights and measures"; Circular No. 43, "The metric carat"; Circular No. 46, "The testing of barometers"; Scientific Paper No. 214, "Note on the setting of a mercury surface to a required height," and Scientific Paper No. 219, "Production of temperature uniformity in an electric furnace." The following proposed publications have been partially prepared: A circular on "The testing of screws and screw threads"; Circular No. 47, "Units of weight and measure; definitions and tables of equivalents," (in press); "Report of the ninth annual conference on weights and measures"; "Measurement of time and testing of time pieces"; "Instructions for the guidance of weights and measures officials"; "Tolerances and specifications for commercial apparatus"; revision of Circular No. 3, "Verification of standards of mass"; and a circular on "Wagon scales."

2. THERMOMETRY, PYROMETRY, AND HEAT MEASUREMENTS.

Calorimetric Resistance Thermometers.

Details of construction and the method of use of special resistance thermometers have been developed by the Bureau for calorimetric measurements requiring the highest attainable accuracy. (See Scientific Paper No. 200.) The construction of these thermometers for the public has been undertaken by a well-known American instrument manufacturer and they have already found extensive applica-

tion in technical and university laboratories. The accuracy attainable with these thermometers is about ten times that previously attainable with the best mercurial thermometers.

Melting Points of the Refractory Elements.

A joint investigation was undertaken with the metallurgical division, for the purpose of determining the melting points of elements of the iron group—nickel, cobalt, iron, manganese, chromium—and of vanadium and titanium by means of the micropyrometer, an instrument developed in the laboratories of the Bureau for determining melting points of minute samples of materials. The melting points observed and the degree of purity of the elements used are stated in full in Scientific Paper No. 205 and lead to the conclusion that the probable melting point of the pure elements are as follows:

Ni	1452° C.	± 3	Cr	1520° C. to Fe?	
Co	1478°	± 5	Va	1720°	± 30
Fe	1530°	± 5	Ti	1795°	± 15
Mn	1260°	± 20			

The paper supplies important chemical and metallurgical data on some of which the existing data was quite conflicting.

Melting Points of Some Refractory Oxides.

A previous publication of the Bureau gave the results of determinations of the melting points of 62 samples of fire brick and of materials of importance in the manufacture of fire brick. Further determinations of the melting points of some highly refractory oxides have been carried out in an electric furnace which could be evacuated or supplied with a current of inert gas. The temperature measurements were made with an optical pyrometer. The melting points found were:

Cr_2O_3	1990° C.	CaO	2572° C.
Al_2O_3	2050°	MgO	2800°

The data are of importance to the ceramic industries and in many high temperature problems, such as the design of furnaces, etc., besides having a general physical-chemical interest. (See Scientific Paper No. 212.)

The Monochromatic and Total Emissivity of Nickel Oxide (NiO) in the Range 600° to 1,300° C.

An investigation has been under way for some time to determine the radiating properties of metals and oxides at high temperatures. In many industrial operations the only available method of measuring the temperatures is by means of optical pyrometers which measure the intensity of the light, or by radiation pyrometers which measure the intensity of the heat (and light) radiations emitted by the hot body, the temperature of which is to be measured. As the radiating properties are different for every material, it becomes necessary to determine these properties to enable the technical man to correct his observed pyrometer readings to the true temperature of the material under observation. These corrections are in some cases very considerable, amounting to several hundred degrees centigrade or more for some of the metals in their molten condition.

In a previous paper (Scientific Paper No. 121), the Bureau published data for correcting the observed readings of optical and radiation pyrometers when used to measure the temperature of red-hot copper, in the solid and in the molten state, when the surfaces were clean and when oxidized. In the present paper similar data are given for nickel oxide surfaces in the range 600° to 1,300° C.

The Specific Heat of Copper.

Copper enters into the construction of calorimeters and its specific heat and the variation of its specific heat with temperature must be known with an accuracy higher than could be obtained from existing data. It was therefore necessary for the Bureau to undertake its redetermination in the ordinary range of temperature of calorimetric work to an order of accuracy demanded by several important calorimetic investigations now well under way in the laboratories of the Bureau.

The copper was annealed wire, 99.87 per cent pure, according to chemical analyses. The results of 27 determinations at temperatures between 15° and 50° C. show an average deviation of 1 part in 1,000 from $0.3834+0.00020\ (t°-25°)$ international joules per gram degree or $0.0917+0.000048\ (t°-25°)$ calories (20°) per gram degree if 4,182 joules be taken as equal to 1 (20°) calorie.

Latent Heat of Fusion of Ice.

The latent heat of ice, or conversely the amount of heat that must be removed from unit mass of water at 32° F. to freeze it to ice at that temperature, is one of the fundamental constants of refrigeration engineering. Previous determinations of this constant are not in good agreement. Engineers in their computations use values ranging from 142 to 144 British thermal units per pound. The Bureau having been asked by refrigeration engineers, through their technical societies, to standardize practice, a new and careful determination of this constant was undertaken by the Bureau. Two independent methods of experimentation were used, which gave results in agreement to about 1 part in 2,000. The result found for the latent heat of ice was, 79.63 calorites (15° C.) per gram mass; 143.33 B. t. u. per pound mass, or 143.5 B. t. u. per pound weighed in air against brass or iron weights.

The results of this investigation were communicated to the Third International Congress on Refrigeration, held at Chicago in September, 1913. (See Scientific Paper No. 209.)

Industrial Gas Calorimetry.

Legal requirements are tending toward the specification of the heating value for gas. An investigation was accordingly undertaken at the request of American gas engineers to furnish information to engineers, inspectors, and public-service commissions as to the sources of error, important precautions in the use of, and accuracy attainable with the various calorimeters widely used in the gas industries.

An exhaustive investigation was made of nine different makes of calorimeter that have found extensive use in the gas industries for the measurement of the heating value of gas. An analytical investigation was made of the various heat losses from the calorimeters;

of modifications in the method of operation to reduce these heat losses; and of the effect of operating the calorimeters at different rates of gas consumption, air supply, etc., and under different conditions of atmospheric humidity; and sources of error in metering the gas. The several gas calorimeters were intercompared and one of them was compared with two calorimeters of the bomb type, using different gases (hydrogen, illuminating gas, and natural gas). (See Technologic Paper No. 36.)

Standard Methods of Gas Testing.

In order to make available to gas engineers and inspectors the results of the exhaustive investigation of gas calorimetry, briefly outlined above, the Bureau has published (see Circular No. 48) specific directions for operating gas calorimeters that will enable the user to obtain accurate and reliable results. It is hoped that this publication will place before American gas engineers detailed directions for an approved and authoritative method of gas testing, thus filling the place in American gas-testing practice that has been filled in English practice by the Notifications of the Gas Referees.

Combustion Calorimetry and the Heats of Combustion of Cane Sugar, Benzoic Acid, and Naphthalene.

The Bureau has designed a special calorimeter for the determinations of the heats of combustion with the highest attainable accuracy, and has measured the heats of combustion of cane sugar, benzoic acid, and naphthalene, the three substances that are now regularly sent out by the Bureau as standard combustion samples and widely used by chemists and engineers for the standardization of the calorimeters used for testing the heating values of fuels, foods, etc. The widespread and growing demand for these standard samples emphasizes the importance of this investigation.

The use of these samples enables the user of a calorimeter to quickly check the accuracy of his work, and has practically reduced the work of all calorimetric laboratories to a uniform and comparable basis. Before such checks on the accuracy of the work were possible, cases had been called to the attention of the Bureau where tests on the same samples of fuels in the laboratories of the purchaser and the seller differed by amounts sufficient to affect the basis of settlement by thousands of dollars annually, as the fuels were purchased on the basis of their heating value. The heating values found were as follows:

Cane sugar=3,949±2 calories (20°) per gram
Benzoic acid=6,329±1 calorie (20°) per gram
Naphthalene=9,622±1 calorie (20°) per gram

where the substances are weighed in air against brass weights.

Cold-Junction Correction for Thermocouples.

Cases have come to the attention of the Bureau where errors in these temperature-measuring instruments as great as 50° C. were possible, owing to erroneous application of the correction for the cold-junction temperature. Scientific Paper No. 202 was written with the aim of impressing upon the technical man the necessity of using some caution in the matter of the cold-junction temperature of thermocouples. This paper gives the details of the methods of applying the

proper corrections and discusses briefly devices for the elimination of the cold-junction corrections.

Ocean Temperatures in the Vicinity of Icebergs and in Other Parts of the Ocean.

The unfortunate accident to the *Titanic* centered attention on possible methods of detecting the proximity of icebergs. Great differences of opinion seemed to exist as to the value of sea-water temperatures for this purpose. The usual method of roughly taking the temperature of a pail of sea water at widely separated intervals of time could give no useful information so far as detecting the proximity of icebergs is concerned. If any definite variations in the sea-water temperature are caused by the proximity of icebergs, then continuous records of the temperature should be taken.

The Bureau having in use in its laboratories instruments for obtaining continuous temperature records, it was deemed of sufficient importance to test the value of such records for the purposes of detecting the near approach to icebergs. The necessary equipment was hurriedly constructed and assembled and, through the courtesy of the Navy Department, installed and operated by representatives of the Bureau on the U. S. S. *Chester* and the U. S. S. *Birmingham*, in the summer of 1912. A specially constructed electric resistance thermometer, together with a Leeds and Northrup recorder, was used to obtain continuous records of the sea-water temperature. This equipment was sensitive to a few hundredths of a degree. Numerous records of sea-water temperatures were taken while approaching and cruising around icebergs and in other parts of the ocean. (See Scientific Paper No. 210.)

The general conclusions reached were that the temperature variations in parts of the ocean far removed from ice are often as great and as sudden as in the immediate neighborhood of icebergs, and that it is not possible to draw positive conclusions as to the absence or proximity of ice from the temperature records of sea water. The temperature records may, however, give valuable information and warning of approach to shore and shallow water, on the location and identification of characteristic ocean currents, and even of the proximity of ice in some parts of the ocean, distant from commingling ocean currents, where the temperature variations are less sudden and erratic than in the regions where the above observations were made.

An attempt was also made to detect, by means of the ships submarine telephones, the submarine echoes, from the submerged portion of a large iceberg, of the sound waves sent out by striking the ship's bell lowered under water. For lack of time and facilities these experiments could not be followed out, but as far as they went seemed sufficiently promising to merit further trial.

The Bureau has had a scientific observer aboard the U. S. revenue cutter *Seneca* in its patrol of the North Atlantic Ocean with a complete equipment for obtaining the necessary physical and meteorological data. This work has been planned by, and is being carried out in cooperation with the Revenue-Cutter Service, the United States Weather Bureau, the Hydrographic Office, and this Bureau. The biological work is being carried out by the Bureau of Fisheries.

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 results of the determinations of the first of these constants, viz, the latent heat of ice, have already been briefly reviewed above. Other fundamental constants on which work is now progressing are:

(*a*) The specific heat of ice.
(*b*) The coefficient of thermal expansion of ice.
(*c*) The specific and the latent heats of the liquids used in refrigeration, such as ammonia, aqueous ammonia solutions, carbon dioxide, methyl chloride, etc.
(*d*) The specific heats of the vapors of the liquids used in refrigeration.
(*e*) The specific heats of brines.
(*f*) The specific volumes of saturated vapors of the liquids used in refrigeration.
(*g*) The densities of aqueous ammonia solutions.
(*h*) The pressure-temperature relations of the liquids used in refrigeration.
(*i*) The thermal conductivities of insulating materials used in cold storage construction, in steel passenger and mail cars, in furnace construction, etc.

Nearly all of the apparatus required for these investigations has been designed and most of it has been constructed in the instrument shops of the Bureau, and the more important pieces of apparatus have been tried out in the laboratory with most satisfactory results. This investigation has involved first of all the original design and construction of a vast amount of accurate and complicated apparatus and the overcoming of what at times seemed most discouraging experimental difficulties. Now that much of this work has been accomplished, it is believed that experimental results will follow as quickly as can reasonably be expected.

The descriptions of the numerous pieces of apparatus, such as low temperature thermostats, calorimeters, mercury manometers, piston pressure gauges, etc., and of the experimental methods that have been adopted can hardly be comprised within the space of a report of this kind. It is believed that most of this schedule can be completed in the course of the next two years, with the completion of which, it is confidently believed, the fundamental constants of refrigeration will rest on a most satisfactory basis for many years to come.

This 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 and keep in close touch with the work, and have rendered valuable assistance by practical suggestions.

Heats of Combustion Gases.

American gas engineers have requested the Bureau to issue an authoritative table of the heats of combustion of the more important gases entering into the composition of manufactured gas. In view of the fact that existing data are discordant and are based on methods that are much inferior to those now available, further work is necessary before such a table can be issued with that degree of confidence which would assure its universal adoption. Most of the necessary apparatus required for this work has been developed and is now at hand and some of the experimental methods to be used have been

tried out in the laboratory. This investigation requires a great amount of chemical work in the production of the various gases in the highest state of purity, and the determination of their heats of combustion in calorimeters of special design capable of yielding results of the highest attainable accuracy.

Resistance Thermometry.

In connection with the calorimetric platinum resistance thermometers that have been developed by the Bureau for measuring small temperature changes of a few degrees with an accuracy of a few ten-thousandths of a degree, it has been necessary to design and construct several special resistance bridges, the details of construction of which will be described in a forthcoming paper.

Heat Capacity of Water and the Mechanical Equivalent of Heat.

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.

Radiation Pyrometers.

One method of measuring the temperature of heated objects, which is particularly applicable to certain technical operations, and which is coming into extended use, consists in the use of a radiation pyrometer, which measures the intensity of the total radiation (i. e., both the light and the longer heat waves) emitted by the heated body. In the work of testing these instruments the fact developed that their indications varied with the size of and with the distance from the heated body, with the time of exposure, with the focusing, etc. Accordingly, an investigation was undertaken of a number of such instruments which had been submitted to the Bureau for test. This work, which is nearly completed, will treat in necessary detail the various forms of radiation pyrometer, their calibration, sources of error, and applications in technical industries. It is hoped that the data which will be submitted will result in a marked improvement in construction, and greater satisfaction in the use of this important type of temperature measuring apparatus.

Radiating Properties of Metals and Oxides.

This data is required to enable technical men to correct the observed indications of optical pyrometers. As stated in a previous section of this report, two investigations along these lines, on copper and

on nickel oxide, have been completed. The radiation from other substances of industrial importance will be examined from time to time as opportunity permits.

Behavior of Base-Metal Thermocouples at High Temperatures.

In view of the extensive use of these couples in the measurement of temperature, it is of importance to determine the changes in their readings due to long-continued exposure to high temperatures. A number of such couples are now under test to obtain such data.

The Thermal Conductivity of Refractories at High Temperatures.

Little reliable data are available on the heat conductivity of building materials. Their conductivity has an important bearing in the use of such materials, upon their behavior under fire conditions, their use in conserving heat, in furnace construction, etc.

The first materials selected were graphite and amorphous carbon, not alone on account of their importance in modern electric furnace construction, but also to test out several new methods of determining thermal conductivities at high temperatures, a constant extremely difficult of determination. The preliminary experiments made thus far promise success.

Industrial Viscosimetry.

The Bureau is constantly receiving requests from technical men for information on the measurement of the viscosity of lubricating oils, one of the important constants that determines the lubricating properties of an oil. More than a score of long letters and reports are prepared annually in reply to such requests. The Bureau accordingly started several years ago to make an intercomparison between the Saybolt-Univrsal, the Engler, and the Redwood viscosimeters, the instruments most widely used in this country and abroad, with a view to preparing conversion tables that would enable technical men to convert their results from the scale of any one to the scale of either of the other two. More assistance should be available for the work. Preliminary conversion tables for the first two of the aforementioned instruments have been furnished to a number of technical men in the reports above referred to.

Low-Temperature Laboratory.

Considerable time of the working force of this laboratory has been devoted to installation and operation of the carbon dioxide refrigeration plant which is in daily use in connection with the problems described under "Refrigeration constants," to the production of liquid air, when required for low-temperature tests, and to the production of pure oxygen and hydrogen for use in the several laboratories of the Bureau. Considerable work has been done in overhauling the liquid air and hydrogen plant, and in the design and construction of a new electrolytic generator for the production of oxygen and hydrogen.

The Fire-Resisting Properties of Structural Materials.

This investigation has been organized during the year. Its scope is so broad that it does not come within this division alone. The planning and carrying out of the high-temperature measurements,

the fire tests of structural materials, the determination of their thermal conductivities, etc., are receiving the attention of this division. The problems relating to the preparation and testing of concretes, tiles, bricks, steel structural material, etc., are receiving the attention of the concrete, ceramic, structural materials, and chemical laboratories of the Bureau; the electrical features of the investigation, such as safety rules for electric wiring, problems appertaining to the national electrical code, etc., are being looked after by the electrical division, while the behavior of these materials under heat as to their expansion, etc., is being investigated by the division of weights and measures.

The present investigation serves as an excellent illustration of the broad scope of an engineering investigation that requires the cooperation of nearly every one of the scientific and engineering laboratories of the Bureau.

During the past year considerable time was devoted to the organization of the work, assembling of the necessary equipment, etc.

One important investigation now well under way relates to the behavior of steel and cast-iron building columns under fire conditions, when exposed and when protected by various kinds and types of fireproofing. We are going ahead erecting buildings and accepting types of building construction, the integrity of which, in case of fire, will depend entirely on the behavior of the supporting steel columns. The building codes of different cities are entirely at variance as to the amount and kind of fireproofing required. It is therefore of the utmost importance that reliable engineering data be obtained on these questions, which are now too much matters of individual opinion. This investigation is being carried out in cooperation with the underwriters and mutual laboratories.

Another important phase of this investigation, which it is hoped will be gotten under way in the very near future, relates to the compiling of the various municipal building codes, not alone with a view to furnishing information to cities and others interested along these lines, but with a view to a comparative study of the codes to assist in planning a systematic program of investigation to answer those questions on which there are radical differences of opinion.

Testing.

A summary of the tests completed in this division during the year is given below.

Over 1,100 mercurial thermometers of various kinds were submitted for test, of which 910 were certified. These tests included many types of thermometers, such as low temperature, laboratory, high temperature, calorimetric, Beckmann, clinical standards, hydrometer, and special thermometers. 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. There were included in these tests 273 calorimetric and Beckmann thermometers intended for use in the determination of the heating values of fuels and many high-temperature thermometers intended to control various technical operations.

Ten thousand and seventy clinical thermometers were submitted for test, 90.7 per cent of which were certified and 9.3 per cent rejected for various causes, such as excessive error, retreating of index,

defects in construction, difficulty in throwing back index. These thermometers were submitted by the several medical bureaus of the Government, State medical institutions, manufacturers, hospitals, dealers, physicians, and individuals.

In addition to the above there were tested in the thermometer laboratory six calorimetric platinum resistance thermometers intended for the measurement of the small temperature changes met with in calorimetry with the highest attainable accuracy. These thermometers, which were developed in the laboratories of the Bureau and fully described in the Bulletin, are finding considerable use in technical and university laboratories.

Of all the thermometer tests summarized above, about 50 per cent were made for the public and the remainder for various technical bureaus of the Government.

Two hundred and seventy-four standard combustion samples of sugar, naphthalene, and benzoic acid were sent out during the year, against 152 during the preceding year, thus attesting to the growing demand for these samples for the standardization of calorimeters used for the determination of the heating values of fuels, and to the increasing practice of basing fuel contracts and specifications on heating-value tests. The standard samples were furnished at the cost of production to numerous industrial plants using large supplies of fuel, such as cement, steel, cotton, and paper mills; coal, oil, and gas companies; electric-power companies; chemical manufacturing plants, etc.; to university, municipal, State, and national testing laboratories and bureaus.

One gas calorimeter of the flow type and one combustion calorimeter of the bomb type were tested and certified. A number of careful determinations of the specific heats of analyzed samples of milk and creams were made for the Bureau of Animal Industry. An extensive series of tests of eight sample refrigerators, of four different sizes, were made for the Office of the Quartermaster General, War Department, as the basis for the award of large contracts. These tests related to ice consumption, temperature distribution, and air circulation within the refrigerators.

About 90 per cent of the calorimetric work was done for the public and the remainder for various bureaus of the Government.

In the high-temperature laboratories there were tested 92 thermocouples (platinum and base metal), 3 platinum resistance thermometers, 7 total radiation pyrometers, 14 optical pyrometers, 17 pyrometer galvanometers, 10 special tests, 26 determinations of melting points of refractories, such as fire and carborundum bricks, clays, infusorial earth, lavite, blast furnace slags, iron ore mixtures, etc.

These tests were submitted by a wide variety of interests, such as iron and steel plants and allied industries; cement, gas, and ceramic plants; electric manufacturing companies; manufacturers of high temperature apparatus, and of watches, tools, springs, axles, automobiles, etc.; technical and university laboratories, etc.

There has been a very marked increase in the amount of testing that the high-temperature laboratory has been called to do during the past year, amounting to above 75 per cent over that of the preceding year, and these demands are steadily increasing, which is satisfactory testimony that American industries are rapidly substituting

careful pyrometric control of high-temperature operations for the old method of eye estimation and other "hit or miss methods."

About 75 per cent of the high-temperature tests above summarized were made for the public and the remainder for various technical bureaus of the Government.

A rather comprehensive test of five electric stoves for heating engravers' plates was made for the Bureau of Printing and Engraving. These tests included measurements of efficiency, of degrees of uniformity of surface temperature, of rate of heating, etc., and were made as a test for a compliance with specifications and as a basis for the award of large contracts.

Two hundred and twenty-five samples of oils, inflammable materials, etc., were tested in this division. These tests were all made for various bureaus of the Government, and tests include determinations of viscosities and flash points for compliance of lubricating oils with specifications, or for their suitability for special uses, determinations of the flash and fire points of materials containing constituents that may make them dangerous in transportation on passenger carrying vessels, etc.

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 lengthy reports, on subjects related to its lines of work. Several hundred such communications were prepared during the year. The requests for information come from nearly every type of industry in which technically trained men are employed, from national, State, and municipal laboratories and bureaus, from scientific investigators, and from committees of engineering and technical societies, and relate to a wide variety of problems, such as, by way of illustration—

Report on fire extinguishers for use on passenger-carrying ships;

Report on air conditioning equipment for the New York appraisers stores;

Summary of scientific literature bearing on the experimental verification of the radiation laws;

Report on the radiation constants of substances, collected from published scientific literature;

The thermal constants of materials, the specific and latent heats of solid, liquid and gaseous substances; the melting points of metals, alloys, and refractories; the thermal conductivities of various materials, such as heat insulating materials used for cold-storage construction, for steel-car construction, for furnace construction, for steam-pipe covering, etc.; the heats of combustion of substances;

Comparators, electric furnaces, etc., suitable for testing various types of thermometers and pyrometers;

Metals and salts of known melting points for checking pyrometers in the works;

Method of high-temperature measurement best suited to particular industrial requirements;

Methods of determining various thermal constants such as specific heats, latent heats, melting points, conductivities, radiating properties, etc., and references to the scientific literature bearing thereon;

Electric furnaces suitable for determination of fusing points of ash, ores, slags, etc.;

Method of applying the cold-junction correction to thermocouple readings;

The temperature of the Bunsen flame;

Method of overcoming vibration of temperature measurements of instruments in steel mills;

The softening temperature of Seger cones used in the ceramic industries;
The making and burning of sillimanite and kaolin refractory tubes for use in high temperature laboratory work;
Radiation and convection from steam radiators; the reduction in heat loss from buildings by double windows;
Methods of calorimetric measurement; strength of bombs; use of standard heat samples, etc.;
The liquefaction of hydrogen; the separation of oxygen from air, etc.;
The definition of the British thermal unit, the calorie, etc.;
Specifications for various types of thermometers;
Legal requirements as to the flash points of oils, inflammables, etc.; methods of measuring viscosities; flash points found with different instruments; specifications for oils.

Technical and scientific men are constantly visiting the laboratories to consult with the men engaged on various lines of work, and in this way, as well as by correspondence, the work of the division is brought into intimate relation with the industries it is intended to serve.

New Work, Equipment, and Personnel.

It is deemed more important that opportunity be provided to complete the investigations already under way in this division rather than to take up any very extensive new lines of work, and yet there are some very important technical problems that the division should look forward to taking up within the next one or two years. These problems will be briefly outlined below.

The routine work of testing, which this division has been called on to do, has grown very rapidly, being over 50 per cent greater for the year just closed than for the preceding year, without any increase in the working force. This has necessarily resulted in delaying, and in many cases in stopping entirely, progress on important lines of investigation. Additional assistance is urgently needed.

Standard Melting-Point Samples.

A number of metals and salts, of accurately determined melting points, should be certified by the Bureau and supplied to technical men to enable them to conveniently check the accuracy of their pyrometers, just as the standard 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. To meet this demand will require an outlay of about $1,000 for a sufficient supply of materials to inaugurate the work and about half of the time of a minor assistant. The fees received for the standard samples would nearly, if not quite, pay for the work and materials.

New Equipment.

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 bomb calorimeters, electric furnaces, heavy current transformers and rheostats, thermocouples, radiation pyrometer, and refractory porcelain for high-temperature work.

3. ELECTRICITY.

Equipping New Electrical Laboratory.

During the first half of the fiscal year the new electrical laboratory was equipped with pipes, wires, switchboards, storage batteries, and other necessary equipment, and the machinery and apparatus moved in from the rooms in three different buildings previously occupied. The large amount of time required for the moving and setting up of apparatus has interfered to some extent with the work of research and testing. Nevertheless, the results of the year show that a considerable quantity of both have been done.

Fundamental Electrical Standards.

The investigations upon the Weston cell as the standard of electromotive force have been continued. An intimate study of the methods of preparing the chemicals used has revealed sources of small variations hitherto unsuspected, and the cell as now made is much more constant in value and more reproducible than formerly. Considerable progress has been made in the attempt to remedy the cracking of the Clark cell, which has heretofore been a serious defect of the cell.

The work on the mercury ohm has been completed, and the report upon it will shortly be ready for publication.

The investigation on the silver voltameter has been continued and two papers published during the year. One was Part IV of the general investigation, and deals with the purity of the materials and other questions affecting the accuracy of the standard, and the other was a paper on the relation of the silver voltameter to the iodine voltameter. This work is of great importance in permitting the international definition of current to be specified with greater accuracy. Specifications for the use of the silver voltameter are being prepared, based on the extensive experience of the Bureau.

Electric-Measuring Instruments.

The methods of testing potentiometers have been thoroughly investigated. New methods for carrying out these tests rapidly and with the highest precision were devised and applied. These instruments are the fundamental means of accurate measurements of voltage, current, and power, and their accurate calibration is important.

Transformer Formulas.

A study has been made of the formulas which represent the behavior of transformers. The formulas in common use depend upon certain assumptions and approximations, which had never before been thoroughly examined. This work makes it possible to predict with greater certainty the behavior of a transformer from its measured characteristics.

Potential Transformers.

A simple method of testing potential transformers has been perfected. The method requires the use merely of wattmeters and other ordinary instruments about a central station. Instrument transformers are in use in central stations where large quantities of

electric power are handled. It should prove of great use to have an accurate method available of standardizing these important transformers which requires only apparatus of the most ordinary sort.

Sensitive Galvanometers.

The object of the investigation is to produce galvanometers which are more sensitive and better adapted to the various needs of the Bureau than are the galvanometers which are on the market. The work will include the determination of constants and behavior of instruments of different make; the study of the theory in the light of the experimental data, and the development of a definite procedure for the design of instruments to have previously selected values of operating constants.

Vibration Electrometer.

Another need which has been felt in alternating-current testing has been met by the design and construction of a vibration electrometer. This instrument is capable of measuring extremely small alternating currents, such as are used in the comparison of small electrostatic capacities.

High-Frequency Instruments.

An investigation was made of the ammeters used in radiotelegraphy. Every radio station has one of these instruments for the measurement of the high-frequency currents used. In many cases they are very unreliable. The sources of error were discovered by a rigid theoretical and experimental research, and means were devised for overcoming the errors and bettering the designs. Some of the work strengthened the application of alternating-current theory to high-frequency measurements.

Decremeter for Radiotelegraphy.

The decrement or rate of decay of the trains of waves emitted by radiotelegraphic antenna is limited by law. The inspectors of this Department have the duty of enforcing the law, and there was heretofore no instrument by which the measurement of decrement could be made with speed and accuracy. A decremeter was therefore designed which has proved itself to be very satisfactory in practice, and which has been adopted by the War and Navy Departments, and by the Bureau of Navigation of the Department of Commerce for the use of its inspectors.

The Standardization of Electric Wave Meters.

It is proposed to set up standard circuits of known frequency in order to show what conditions affect the precision of wave meter measurements and to improve the accuracy of such measurements; also to give typical examples of the behavior of various wave meters.

Inductance, etc.

A study is being made of the effective resistance of copper-clad iron and steel wires to obtain data concerning the electrical properties of conductors containing an iron core over a considerable range of sizes, current strengths, frequencies, and magnetic properties. Such data can only be determined experimentally, and no previous

work has covered the field. Such conductors are used commercially in telephone, telegraph, and power transmission work.

Methods for measuring the inductances of very small resistances were devised and tried out. These methods increase the accuracy of alternating-current tests at the Bureau and other standardizing institutions.

Properties of Dielectrics.

An investigation of the insulating properties of solid dielectrics has been in progress for some years. The insulating materials used in electrical work are many, and the accuracy of all electrical measurements depends on the reliability of the insulators. Hard rubber and its many substitutes are the most important in the building of electrical measuring instruments. A great many of those in common use were tested for leakage of current through the material and across the surface of the insulator. The effect of leakage across the surface of these substances is tremendous, some of them having a resistance millions of times as great in dry weather as in damp weather.

The Decrements of Coupled Circuits.

The object is to establish with greater certainty the formulas used in the measurement of high-frequency resistance, to extend the known formulas if possible, to find an expression for the errors in these formulas, and to make available in English much material hitherto in German only.

Magnetism.

Much work has been done on the relation of magnetic to mechanical properties of steel. The steels investigated cover a considerable variety of chemical composition and thermal treatment. Full-sized steel rails are included in the investigation. It is hoped that the information obtained will be of great value in the practical testing of steel. It has been found that the permeability of ordinary steels changes appreciably with temperature. This is under further investigation.

The study of core loss at the higher inductions has progressed rather slowly owing to difficulties met in the determination of the form of the wave of electromotive force. The bismuth spiral, well known as a convenient means of measuring magnetic fields, has been found to have several peculiar properties. Careful study of this is in progress. These lines of work are of the greatest interest to electrical engineers and to research laboratories.

Radium.

The intercomparison of sealed radium standards and the study of the gamma-ray method of radium measurement have made satisfactory progress, and very accurate measurements are now regularly made. Studies are being conducted of the alpha-ray activity of powdered material, of the activity of uranium mixtures, and of radium ores and radium emanation. The radium laboratory has made numerous tests of specimens to determine the amount of radium present, and hence the money value.

Gas Photometry.

The pentane lamp as a working standard in measuring the candlepower of gas flames has been under investigation for some years. A paper on this lamp as a working standard was published. The information given enables municipal inspectors, gas companies, and others to obtain more accurate measurements than heretofore, by taking proper precautions in the use of the lamp.

Flame Standards in Photometry is another paper published during the year. This gives results obtained on the Hefner and pentane lamps with regard to their reproducibility and the effect of variations in atmospheric humidity and barometric pressure.

Color Photometry.

Considerable progress was made during the year on the difficult problem of color photometry, i. e., measuring the candlepower of lamps having widely different colors. One of the most convenient methods is by the use of colored glasses to bring the lamps to a color match, but the calibration of these glasses must first be made. The percentage of light transmitted by these glasses for different colors and under various conditions was studied. The equations of the curves expressing the relation between candlepower and voltage, watts per candle and voltage, etc., have been derived for tungsten lamps, and it is found that they apply very exactly for lamps of different makes and even of different methods of manufacture. Their use will permit standard lamps to be used at any desired color or efficiency within a considerable range, and thereby avoid color differences in measurements. The work is nearly ready for publication.

Effect of Atmospheric Conditions on Flame Standards.

A study is being made of the effects of atmospheric conditions on flames, particularly to determine effects of barometric pressure and of humidity on the intensity of the light emitted by flame standards of candlepower and by gas flames. The work will include photometric measurements on flames under varying natural conditions, and similar measurements on flames in an inclosure to which a compressor furnishes air under high or low pressure, variations in humidity being obtained by drawing the air through water or over drying material. Results so far obtained are of great interest and importance, and the work will shortly be ready for publication.

Electrical Testing.

The following list of instruments and materials tested during the year is arranged in six groups, corresponding to the six sections in which the electrical testing is done. The more important tests for the Government are so marked. The remainder are nearly all for the public.

The following tests were made of standard cells, standards of resistance, resistance apparatus, and electric conductivity of materials: 85 portable or unsaturated Weston cells, 4 saturated Weston cells, 69 resistance standards, 9 shunts, for current standards, 3 volt boxes, 4 potentiometers, 1 slide wire, 2 Wheatstone bridges, 3 resistance boxes, and 58 conductivity samples (42 for the Government).

The tests of inductance, capacity, radium, and radioactive substances included: 19 electric condensers, 10 samples of telephone cable, 15 inductances, 2 tests of insulation resistance, and 28 specimens of radium salts (aggregate value of the radium contained, $58,000).

The tests of electrical measuring instruments, transformers, etc., included: 15 voltmeters, 19 ammeters, 7 wattmeters, 29 watthour meters, 12 instrument transformers, 1 frequency meter, 56 dry cells, 4 primary cells, 24 wire samples, 2 porcelain spools, 178 pairs rubber gloves (for the Government), 41 electric fans (for General Supply Committee), 5 samples of insulating varnish, 7 telephone jacks, and 2 recording potentiometers.

Wavemeters, decremeters, high-frequency ammeters included: 4 wavemeters, 35 decremeters (for the Army and Navy and Bureau of Navigation), and 2 high-frequency ammeters.

Magnetic materials were tested to the extent of 78 permeability and hysteresis tests of iron, and 24 core loss in sheet iron.

Photometric testing, 109 electric lamps were tested for candlepower, and 1,800 tungsten and carbon filament lamps were tested for life, and 1,092,549 tungsten and carbon lamps were inspected for the various Government departments.

Other photometric tests included: 12 pentane lamps for photometric standards, 23 reflectors, 7 portable photometers, 2 arc lamps, and 14 street series tungsten lamps.

Information Furnished on Electrical Subjects.

In addition to information furnished in connection with the various investigations and tests, the electrical division has furnished miscellaneous information on a great variety of subjects.

Requests have been answered for definitions of units from the American Society of Mechanical Engineers, from the French Government committee on systems of units, and from editors and others. There has been some difficulty in furnishing full information on the electric units and standards, as there is no single, consistent compilation of data on this subject. Because of this fact, work has been begun upon a circular treating the subject in a complete and thorough manner.

There are occasional requests for revision of physical tables. Considerable data were furnished for the Smithsonian Physical Tables, for a special book of "Conversion Tables," and for other sets of tables.

The numerous inquiries regarding electric measuring instruments are in many cases answered by sending the inquirer a copy of the Bureau circular on this subject. The many developments and improvements of the last five years in this field required a revision of the circular. This has been done, and the circular is now thoroughly abreast of the times and is a valuable compendium of information.

The Bureau has furnished considerable information regarding the electrical constants of copper to the International Electrotechnical Commission, through its American committee. The investigation on the conductivity and temperature coefficient of resistance of copper, which was conducted here in 1910, was considered a suitable basis for an international standard. Such a standard is useful for the expression of per cent conductivity, and in the preparation of wire tables.

The question was considered by international committees and by the committees of various national engineering societies. Information was sought from the Bureau at all stages of this consideration. Besides furnishing the data asked for, the Bureau prepared a very complete set of copper-wire tables, with explanations and historical discussions of the allied subjects.

This work culminated in the adoption of the values upon which our tables are based as international standards. This action was taken by the International Electrotechnical Commission in plenary session at Berlin in September, 1913. The circular on this subject has since then been revised and a new edition prepared. The new copper standards have been adopted in the 1914 Standardization Rules of the American Institute of Electrical Engineers. The British engineering standards committee also has taken up the work of revising its tables to bring them into conformity with the international standard. This is the first time that the electrical engineers of all nations have had a common standard for copper. Following the international adoption, there was considerable correspondence with the commission and with the other national standardizing laboratories to settle certain questions regarding the numerical values.

In the revision of its standardization rules, some assistance has been rendered the American Institute of Electrical Engineers. This assistance includes the furnishing by the Bureau of the material for the new section on wire and cable standardization. There was considerable discussion and correspondence regarding some of the definitions, and two discussions of certain provisions of the rules were published in the technical press by members of the division.

Some inquiries on the definitions of units of force and power have arisen as a result of the Bureau's circular on horsepower. These have led to a thorough revision of said circular, with the addition of discussions of the units of force and standard values of gravity.

There have been numerous letters asking the Bureau to pass an opinion upon pseudoscientific discoveries and inventions. Men of limited education or equipment who believe they have made wonderful and revolutionary discoveries often possess extraordinary confidence in themselves and their work, and it is exceedingly difficult to convince them of the fact that some things are definitely known to be impossible. The Bureau has, however, been able to render some service to the public by replying to inquiries concerning the worth of some of these schemes, especially those in the perpetual-motion class.

Investigators and radiotelegraphic companies have sought information on the calculation of inductances. Some of these inquiries could be answered by reference to our Bulletin articles on the subject, while others required some independent work.

In the field of radiotelegraphy, the Bureau has been called on for considerable information. Assistance has been rendered the Bureau of Navigation of this Department on questions relating to the measurement of wave length and decrement, interference caused by arc stations, and transmitting and emergency sets. As a result of our advice on the latter subject, the ships equipped by certain commercial companies have discarded the emergency sets formerly used and adopted others, based on the methods suggested. Information has been furnished regarding the radio equipment of small boats such as revenue cutters, and of lighthouses for fog signaling.

Amateurs have sought information regarding the legal regulations and regarding operating questions. These inquiries make it appear that a general circular of information on radiotelegraphy for amateurs and others would be very desirable, and the preparation of such a circular is projected for the coming year.

The work already done on sensitive galvanometers has made it possible to furnish information to various investigators as to the construction of very sensitive instruments for special purposes.

There have been many inquiries regarding the testing of radium and of radioactive waters and allied questions.

In magnetism there have been requests for typical data on the magnetic constants of various grades of steel used for electromagnets and permanent magnets. Reliable data on these matters would be very valuable, but have never been collected from the abundant literature. The necessary time has not yet been found to take it up systematically.

Information has been furnished as far as available in the subjects of street-lighting specifications, headlights and projectors, and illuminating-oil specifications.

Public-Utility Investigations.

The above statements of investigations completed or nearly completed, of publications, of testing, and information supplied to the Government and the public, covers in large part, though not completely, the work of the electrical division, which consists principally of laboratory work and testing. The remaining work has to do largely with public-utilities service, and consists of scientific and engineering researches, the study of public-relations questions, and the collection and distribution of information. This work may conveniently be described as follows under separate headings.

Service and Standards for Illuminating Gas.

This work has been carried on for several years under the direction of the electrical division, with the cooperation of 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 invstigations carried on by the Bureau for the past five years on these subjects, which have resulted in a considerable number of papers published in the Bureau's scientific and technological series, a thorough 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 three years ago. This was revised and republished a year ago and is now being revised for its third edition. This publication has had a wide circulation and serves a useful purpose in setting forth the proper basis for regulations, discussions as to the relation between the quality of gas

and the efficiency of manufacturing processes, and the most satisfactory terms of specifications of quality and methods of testing.

Another publication which will shortly be issued is Circular No. 48, which will give a detailed technical discussion of methods of gas testing. This will be 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. 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.

Another important work in which the Bureau hopes to do more during the coming year is the inspection of testing laboratories and equipment, both of companies and the public, with a view of getting information for our own use and of giving suggestions or information that would improve the accuracy or efficiency of the testing. The information secured would be used in connection with publications on laboratory equipment and testing methods. It would enable the Bureau to keep in closer touch with the industry and the regulating bodies that represent the public and to give more valuable information when called upon.

One of the most important and at the same time difficult questions for a regulatory body to decide is the quality of gas that shall be specified. Gas is measured by meters, which register in proportion to the volume of gas passing, expressed in cubic feet. This volume of a given mass of gas varies according to its temperature and pressure, the latter varying with altitude above sea level. It is its mass or effective quantity that determines its usefulness, rather than its volume merely, and hence some very complicated questions arise when one attempts to prescribe how it shall be measured and tested and be fair and just both to the company and the public. The Bureau has discussed these questions fully in its publications, and has recently carried out some extensive measurements on the variation of the light of pentane and Hefner standard lamps with atmospheric pressure, and the variation of the luminous efficiency of gas flames with the pressure of the atmosphere.

Electrolysis Mitigation.

The greater 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, much 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 form iron pipes or lead cable sheaths, it carries away iron or lead by electrolytic action, and this in time often eats holes into the pipes and sometimes completely destroys them.

The trouble is the more serious in places where the soil has a greater conductivity than usual, and also where the car tracks are fewer 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 destructive effects of these currents, 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 four 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 work was done in St. Louis, Springfield, and Elyria, Ohio, and Springfield, Mass., and reports prepared, some of which were published during the year.

The recent electrolysis survey in Springfield, Mass., 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 currents, 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.

This work will be continued during the coming year, and it is hoped that the Bureau's work will induce railway, gas, and water companies generally to make electrolysis surveys, and the railways to giving more attention to bonding of tracks and the provision of adequate return conductors for their current, so that less current will get into gas and water pipes and cable sheaths.

The work of the Bureau 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.

The following technologic papers on this subject were issued during the year:

Surface Insulation of Pipes as a Means of Preventing Electrolysis (No. 15), an experimental study of a great number of pipes, coatings, and wrappings, and the effects on the electrolytic corrosion of underground pipes.

Electrolytic Corrosion of Iron in Soils (No 25), a study of the effect of current density, moisture, temperature, and oxygen upon the corrosion of pipes, and the bearing of the results obtained upon electrolysis mitigation in practice.

Special Studies in Electrolysis Mitigation, No. 1 (No. 27), a preliminary study of conditions in Springfield, Ohio, with recommendations for mitigation.

Special Studies in Electrolysis Mitigation, No. 2 (No. 32), an experimental test on a system of insulated negative feeders in St. Louis.

Electric Light and Power Service.

During the past year we have been studying the question of the specifications of 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 for heating and illumination. The principal factors of such service are its quality and reliability, and the accuracy of the meters that measure it. Steadiness of voltage, without which electric lighting is not satisfactory, and continuity of service are phases of quality 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 vary under different conditions, and as there has been relatively little experience so far in the enforcement of some of these requirements, there is ample room for study by the Bureau, this study including consultation with a great many operating companies and the collection of results obtained under various kinds of regulatory ordinances.

The feasibility of making requirements of this kind in the case of the smaller utilities is a question deserving careful study. The extent to which automatic voltage regulators, recording voltmeters, pressure wires and instrument and meter-testing outfits can be utilized by such small companies without undue hardship, and possibly a resulting detriment to their customers, is a question of great practical importance, and we are planning to give considerable attention to it during the next fiscal year.

During the past year the Bureau answered many inquiries for information, assisted cities and commissions in preparing regulations, while a representative of the Bureau has conferred with numerous companies and commissions regarding the questions we are studying. Here, as in other lines of our public-utility work, we aim to serve in some degree as a clearing house of information, although this work is so recently established that it has so far made only a beginning. An increased force is much needed to strengthen the work.

Life Hazard in Electrical Practice.

For many years the National Fire Protection Association has studied the question of fire hazard due to electrical apparatus and machinery and conductors carrying electric currents, and the underwriter's code, prepared and frequently revised by this association, has been generally adopted and enforced in order to reduce the fire hazard. But there has been no national body doing a corresponding

work to reduce the life hazard, while the number of serious accidents and fatalities to linemen and other employees and the public has been increasing year by year.

The matter became so serious that the Bureau secured from Congress authorization and a special appropriation to study the question. During the past year this study has been in progress, with a view to preparing safety rules to be observed in the construction and operation of electric light and power plants, and in the distribution and utilization of electricity. Attention is given also to the fire hazard, and in this we are cooperating with the underwriter's laboratories and the National Fire Protection Association. The first set of rules on the operation of electrical equipment and lines has been completed, with the cordial cooperation of many electrical companies and public bodies, such as State public-service commissions and State industrial commissions. It is expected that these rules will be widely adopted, and will tend to reduce accidents and assist in securing a much desired uniformity of practice among the different States.

An interest has been awakened throughout the country in the question of greater safety, and the work of the Bureau in the more technical aspects of this safety movement so far as the electrical industries are concerned, is very timely. The public is vitally concerned, also, for the use of electricity is so general, both in the household, in the industries, and in transportation, and its distribution circuits form such a network in most communities that one can not know when he is free from danger unless there is close public supervision both as to construction and operation. Effective supervision requires adequate and carefully prepared rules or specifications that can be readily understood and intelligently followed.

This work will be continued and enlarged during the next fiscal year by the addition of another engineer to the two already engaged in this work.

Illuminating Engineering.

Provision is needed to enable the Bureau to take up in an adequate manner the many urgent problems in illuminating engineering. 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 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 that 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.

Radiotelegraphy Research Laboratory.

One of the important needs of the Bureau is appropriate space for research in radio communication, or wireless telegraphy, as it is usually called. For several years the Bureau has afforded space and experimental facilities to the Army and Navy for certain of their investigations in this subject, and has itself done some research work of this kind besides doing testing of instruments used in wireless measurements. But with the rapid development of wireless, the increase in the power used and the distances reached, and especially with its general use at sea for all kinds of service, the small space and meager facilities that can be spared are entirely inadequate. To meet the present needs as to space and experimental facilities, a separate building with special facilities should be provided.

An estimate was submitted last year for $50,000 to erect such a building, but the appropriation was not made. It is recommended that this item be again included in the estimates for the coming year. It is proposed to locate this laboratory directly south of the electrical laboratory, connecting it by a pipe and wire tunnel, so that the experimental machines and sources of current of the electrical laboratory shall be available. This building would provide accommodations for the work of the Army and Navy that has been located at the Bureau for several years. In addition to the sum estimated for the building, an additional sum will be needed later for apparatus and equipment.

Additional Facilities Needed.

With the additional space afforded by the new electrical laboratory building, the electrical division is now in much better condition to do its work than heretofore. Owing to the pressure of testing, however, the research work in some lines has suffered in recent years, and it is hoped that several additional assistants can be provided. In the matter of absolute electrical measurements, in which the Bureau has done conspicuous work in the past, there is needed an additional force to replace those drawn off to do other work for which there was urgent demand. Considerable new apparatus is also needed to make the equipment satisfactory for the work to be done.

The sum available for work on public-utility problems should be increased, to enable the work to be done better and to permit taking up some phases of the work not so far touched.

4. OPTICS.

Determination of Standard Wave Lengths.

The determination of standard wave lengths of light throughout the entire spectrum is at present confined to fundamental work that must be done before wave lengths can be accurately determined. This is being done by the Bureau, in accordance with the recommendations of the International Solar Union, a body whose membership comprises the greater part of the eminent spectroscopist of the world. While the results are needed mainly by scientists, they are also necessary in the industries. For example, the spectroscopic analysis of steel and other substances can not be successfully undertaken until

the characteristics of the spectra of the constituents are more accurately observed. This requires wave lengths of standard or known values. The instruments necessary for carrying on this investigation have been designed during the past year. That part of the apparatus necessary for the work in the ultra-violet part of the spectrum has been constructed and found to be satisfactory. The mounting of a concave grating spectroscope is in progress. About one-seventh of the measures of standard wave lengths have been completed.

Spectroscopic Testing.

Spectroscopic tests have been made of the transmission of glass for the ultra-violet rays, mainly with a view to determining their fitness for spectacle making. Assistance has been rendered to several departments of the Government and to various individuals and firms. Spectroscopic measurements are becoming more and more important, not only in scientific work but in illuminating engineering, the testing of materials, and industrial processes. Such tests are often useful to determine the presence of elements in very minute quantities. With the new grating spectroscope it will be possible to take up this work more effectually.

Standard Samples of Pure Gases.

There have been several demands for standards of pure gases. While the spectroscopic division will soon be able to test the purity of gases, it is not yet feasible to undertake to furnish gases in a state of sufficient purity to serve as standard samples.

Polarimetry.

The polariscope and its accessories are the indispensable adjuncts of the refined-sugar manufacturer, the beet and the cane sugar planter, public sugar chemists, and the customs sugar laboratories. In addition, they are part of the regular physical and chemical equipment used in other industries as well as institutions of learning. The importance of the investigation and standardization of this apparatus has seldom been appreciated by other than scientific workers; it has been found necessary to discard many of the results and methods of the past. In addition to a common basis of standardization, a unification of methods is necessary if the results of different laboratories are to be brought into agreement. During the past year a circular (No. 44), entitled "Polarimetry," has been completed and given a fairly wide distribution among workers in this field. This circular describes approved methods of polarimetric analysis, and shows improved types of apparatus, some of which have been developed at the Bureau.

Conference of Polarimetric Experts.

The general interest aroused in polarimetry by the distribution of this circular has suggested the calling of a general conference of those interested in polarimetric work. The numerous troublesome questions arising from differences in methods would be discussed and probably eliminated. There would also result a wider dissemination of information relative to the standards adopted by the Bureau than could be secured in any other manner.

Influence of Atmospheric Conditions in the Polarimetric Testing of Sugars.

A research of importance to the sugar industry, and of considerable theoretical moment, has been completed on the influence of atmospheric conditions in the polarimetric testing of sugars. The influence of atmospheric conditions on the testing of sugars has not been well understood, owing to the difficulty of controlling both temperature and humidity in the research laboratory. Relatively large and inexplicable differences have been noted for some time between the tests on imported sugars for the collection of duty at the various ports of entry. So great have been these differences that it is probable that sugars have purposely been imported via certain ports with the intent of paying a lower rate of duty. The Bureau's investigations not only shows the exact cause of the differences, but also a simple and certain method of eliminating them.

Study of the Basic Lead Acetates.

Another polarimetric investigation consisted of a study of the basic acetates of lead used for the clarification of the opaque solutions of raw sugars for optical analysis. This research has covered ground which is essentially new and has shown what basic acetates of lead may exist and what is their behavior in aqueous solution. It has been shown that most of the previous work on this subject is in error.

Determination of the 100-degree Point of the Saccharimeter.

This research has been under way for several years, and the results are now being prepared for publication. Being essentially precision measurements of fundamental constants, the greatest care is being exercised to insure the accuracy of the values. By this investigation the Bureau has established the most important fact that the basis of calibration of the saccharimeter (a particular form of polariscope), used the world over in sugar analyses, is in error by over one-tenth of 1 per cent, resulting in a considerable loss to the Government in duties collected on imported sugars and, in addition, the producers of raw sugars have received less compensation than they should have received.

Precision Polariscope.

The large polariscope designed and built by the Bureau for magneto-optical work has been tested and found satisfactory. This equipment now constitutes an invaluable auxiliary for the study of optically active substances, as well as substances not in themselves active, and has opened up a large and important field for investigation.

Preparation of Standard Sugars.

The work on the preparation of dextrose has been continued and standard samples have been issued. This substance which is prepared in the laboratory from the crude glucose is intended as a standard to assist in bringing about uniformity of analysis of a class of substances known as reducing sugars. The investigation of dextrose will be continued. Fifty-eight standard samples of sucrose and seven samples of dextrose were furnished to the public.

Another substance which occurs in sugar mixtures to a slightly less extent than dextrose is levulose. The rotation of this substance

has been but little studied, although its frequent occurrence necessitates continual use of such data as exist. The pure substance is prepared with very great difficulty, but a considerable quantity has been prepared, and during the ensuing year the Bureau will be able to begin the measurements upon it.

Supervision of the Customs Service Sugar-Testing Laboratories.

The important changes made a year ago, including the introduction of the bichromate light filter and the improved polariscope tube, have given excellent results, and the systematic differences existing between the tests of the various ports of entry have grown less. Protests on sugar entries have practically been eliminated.

The Bureau cooperates with the Customs Service in all matters pertaining to the weighing, taring, sampling, and polarization of imported sugars and molasses. The regulations governing the polarimetric work of the Customs Service, and which were prepared in cooperation with the Bureau, are given as an appendix in the polarimetric circular.

Polariscopic Testing.

During the year approximately 1,500 polarizations of sugar were made principally in connection with the control samples sent daily from the various ports of entry for sugar.

Interferometry.

By interferometry is meant measurement of length where the principle of interference of light is applied and where light waves of a particular length are used as a working standard. This method is susceptible of great accuracy, and is particularly adapted to the measurement of very small lengths or changes in length. By it, changes as small as the one-millionth of an inch or even smaller may be measured under favorable circumstances. Important applications are now being made at the Bureau as given below.

Expansion of Materials Due to Temperature Changes.

New apparatus has been designed for temperature control and regulation in measurement of expansion of small samples (a few millimeters, i. e., less than one-half inch), by interference methods. This apparatus was nearly ready at the end of the year. Measurement of the expansion of small samples from steel in connection with the investigation of properties of rails was pending at the close of the year.

Planeness and Parallelism of Surfaces.

A number of tests of planeness and parallelism of optical surfaces and gauges have been made by means of interference methods. The high degree of accuracy required in optical work of this nature can only be secured by the use of this method. It is no unusual matter for the optician to work to the one-hundred thousandth part of an inch or less in the preparation of plane surfaces, which are often quite as essential as a lens in the optical system of an instrument.

Determinations of the Optic Axes of Crystals.

The determination by interference methods of the direction of the optic axis, in quartz plates, such as are required for standards in

sugar analysis, color specifications and expansion measurements, has now been reduced to a satisfactory routine. A number of plates, most of which were constructed in the Bureau's optical shop, have been tested.

Specification and Measurement of Color.

The investigation of methods of specification and measurement of the color of cottonseed oil, undertaken at the request of the Society of Cotton Products Analysts, has been continued. Extensive tests of the applicability of the quartz colorimeter to this problem were made in cooperation with that society, and an instrument was designed and constructed at the Bureau for use in this connection.

The investigation of methods of specifying the color of butter and oleomargarine has been continued at the request of the National Dairy Union, and the Dairy and Food Department of the State of Minnesota. A new method has been devised which it is expected will simplify and facilitate the specification of the color of these particular substances. Some tests of this method were made, and the results communicated to the National Dairy Union. Preparation has been made for carrying out further tests in cooperation with the Dairy and Food Department of Minnesota.

An investigation of rosin colors and proposed standards for the color of rosin has been undertaken at the request of the Bureau of Chemistry of the Department of Agriculture. Partial reports have been made and the work was in progress at the close of the year.

The question of color standards, the specification of color and color measurement, is of such pressing importance to so many industries—such as paper making, lithography, ceramics, textiles, dairy products, paints, oils, dyes, inks, and others—that a special appropriation should be procured to enable the Bureau to expedite this work, which can only be taken up in a limited way with the present staff and equipment.

Colorimetric Testing.

Tests involving about 25 different samples and several thousand observations by different observers have been made in colorimetry and spectrophotometry. There has been a marked increase in the demand for tests of spectral transmission, i. e., the relative transmission of substances for light of different wave lengths. Tests of this kind have been made for glass manufacturers, opticians and consulting engineers. Three pairs of smoked glass photometric wedges have been calibrated for the Johns Hopkins University. Extensive tests of the color of oleomargarine have been made for the National Dairy Union.

Information as to Color Specification and Measurement.

Information relative to the specification and measurement of color has been given to many individuals and firms, as well as to the Society of Cotton Products Analysts, the National Dairy Union, the Bureau of Chemistry of the Department of Agriculture, and to the American Society for Testing Materials. A color screen of prescribed properties designed to reduce sunlight to skylight was prepared and tested at the request of the Weather Bureau.

Color Blindness.

Some attention has been given to methods of testing for color blindness and defective color vision. This question is now of pressing importance to the Bureau in connection with the observers in colorimetry and photometry.

Turbidimetry.

To meet a long-felt need for a more precise standard of turbidity, especially in water analysis, a new instrument for measuring turbidity, known as a "turbidimeter," has been designed and constructed. It has been found satisfactory, and extremely sensitive. An improved instrument is being made which will be suitable for use in standardizing the turbidity not only of liquids, but of gases and solid plates.

The committee on the revision of the standard methods of water analysis, of the American Public Health Association, and the American Chemical Society, have asked the Bureau to cooperate in the revision of the standard of turbidity. An adaptation of the turbidimeter is being planned to be used in the study of fog as a part of the work of the international ice patrol.

Transparency, Translucency, Diffusion.

Methods have been developed and put into practice for testing of transparency, translucency, and opacity of materials, such as glass, paper, and tracing cloth. There has been a marked demand for such tests. Tests of this kind have been made for the Post Office Department and the Customs Service, and for firms or dealers in tracing cloth.

Tests of the distribution of light transmitted by skylight glass were also made.

Investigation and Design of Optical Systems.

The essential feature of many optical instruments often consists of a system of lenses, mirrors, prisms, or other optical parts. The investigation, design, and testing of these optical systems forms one of the principal lines of optical work in the Bureau, as such instruments are in very general use, both in scientific work and by the public. Microscopes, telescopes, field glasses, and photographic lenses are examples.

Apparatus has been designed and constructed for the purpose of obtaining the axial light transmission of optical instruments. This transmission is the ratio of the light which actually reaches the eye, to that which would reach the eye through an exactly similar instrument composed of ideal lenses having no loss either by reflection or absorption. The principal application of these measurements has been to telescopes of all kinds, especially those intended for use under exacting conditions of light. Some have been found which transmitted much more than others, and the indications are that such instruments will be improved in this respect.

The determinations of the secondary standards of wave lengths require the use of a special spectroscope giving good definition along a spectrum line instead of across the line as in the usual types. The optical system of such a spectroscope has been designed and com-

puted. The system is composed of quartz and rock salt and gives a flat field over a long region of wave lengths in the ultra-violet part of the spectrum.

The design of a special photograph lens having a large flat field has been undertaken for astronomical purposes.

Testing of Optical Systems.

The testing of optical systems has been done largely for the different departments of the Government. These tests embrace the various types of optical instruments, including microscope objectives, refractometers, photographic lenses, telescopes of all kinds, binoculars, and various minor optical instruments. Considerable improvement in the optical quality of instruments has been noticed since this testing has been carried on. For example, the magnification was frequently found to be marked wrongly by at least 15 per cent, while at present the error rarely exceeds 3 per cent. Other points have been improved, especially where the defects were not easily apparent in ordinary use, such as light gathering and definition.

Considerable time has been devoted to consultation work with the various bureaus of the Government, as well as the different divisions of this Bureau, in reference to the design, specification, testing, and use of optical instruments.

Refractive Index.

Refractive index determinations are used frequently in place of chemical analysis when a mixture is known to be composed of two compounds, but their ratios are unknown; also as a test of purity where additions of adulterants produce a decided variation. In order to rapidly determine these refractive indices, refractometers are used, and these must be calibrated and should be checked at intervals. For this purpose an investigation is in progress for the purpose of ascertaining the permanence of certain oils which may prove satisfactory for standard refractive indices. These oils were accurately determined after special aeration and carefully bottled. Another determination will be made at the end of about 12 months.

Attempts have been made to prepare standard samples of glass which are required for the calibration of other types of refractometers. The difficulty lies in obtaining glass sufficiently homogeneous, two samples take from the ends of a bar of the best plass only 8 centimeters long differed by 12 units in the fifth place.

A preliminary study has been made of the best methods of determining refractive indices from the viewpoint of both accuracy and rapidity as well as the value of these determinations in the arts and sciences.

Testing of Materials for Refractive Index.

Six samples of standard turpentines and two samples of Chinese wood oil were secured from the American Society for Testing Materials, and the refractive indices of these samples were determined at 15°, 25°, and 35° C., as well as the specific refractions. This work was done in conjunction with the general investigation carried out by the other divisions.

Tests have been made of the refractive indices of solids and liquids, change of the index of refraction due to changes in temperature, strains in optical glass, and other tests of minor importance.

Radiometry.

Measurements of the energy transmitted by radiations, of which light and radiant heat are types, enter into many scientific investigations, both as to the nature of such energy and as to the properties of materials. They are of great importance, not only in physics and chemistry, but also in physiological investigations. During the past two years investigations have been pursued with a view to obtaining uniformity in radiometric measurement. The Bureau has developed instruments, methods, and standards of radiometry which are giving a new impetus to investigations in this complicated field of research and measurement.

Numerous instruments for measuring radiation (thermopiles) have been designed to meet various requirements; for example, one was designed suitable for delicate physiological investigation in nerve and muscle reaction. A new vacuum radiometer was designed suitable for the measurement of the radiant energy from stars. This involved the development of a convenient method of maintaining the thermoelement in a vacuum. This was done by means of metallic calcium which rapidly absorbs the air contained in the radiometer, thus avoiding the use of the ordinary heavy air-pump equipment.

Nocturnal radiation is usually a loss of heat from terrestrial substances into space. A radiometer was designed for the United States Weather Bureau for investigating this nocturnal radiation. A paper has been prepared on the latest developments in instruments and methods of radiometry. In it are given various improved modifications of the bismuth-silver thermopile which have been developed in this Bureau.

Standards of Radiation.

The Bureau has established standards of radiation in the form of incandescent lamps. In these standards the intensity of the radiant energy per unit area at a unit distance from the lamp, has been established in absolute value, first, by comparison with a black body in which the coefficient of radiation was assumed, and second, by direct determination of the intensity of the radiant energy in absolute value. The two methods gave values which are in agreement within 0.5 per cent. Hence, the standard of radiation as defined by these incandescent lamps may be considered well established. That they will supply a long-felt need is evidenced by the fact that copies were at once ordered by experimenters in this country and abroad.

Measurements were also made on subsidiary standards, including the Hefner lamp and the sperm candle. The results are embodied in a short paper submitted for publication.

Stefan-Boltzmann Constant.

Considerable progress was made in the work on the coefficient of total radiation commonly called the Stefan-Boltzmann constant.

With the instrument used in establishing the above-mentioned radiation standard, measurements were made on the total radiation

from a uniformly heated inclosure, or so-called black body. The value obtained for this constant ($\sigma=5.6\times10^{-12}$ watt cm $^{-2}$ deg $^{-4}$) is in excellent agreement with previous determinations by other methods.

Absorption Constants of Quartz.

During the year an investigation was completed on the absorption constants of thick cylinders of quartz. The data are to be used in furthering the work on the constant of spectral radiation of a black body. The results are embodied in a paper now in press.

Radiometric Testing.

There is but little of the so-called routine testing in radiometry. The tests that do arise usually require a very considerable amount of original research. Several such tests were completed during the past year. One was concerned with incandescent lamps giving a standard spectral energy curve in the visible spectrum; another involved the question of the quality of the radiation from a straight and a spiralled filament of tungsten in a nitrogen-filled lamp; also, the determination of the spectral energy curve of this type of lamp in the visible part of the spectrum, when the lamp is under normal operation.

In conclusion, it may not be out of place to call attention to the desirability of pursuing scientific investigations, even though at the time they may not appear to have a direct commercial application. For scientific purposes the Bureau made an investigation to find a substance which completely absorbs all the infra-red or heat rays (which amounts to about 95 per cent of the radiations from the electric arc lamp) and at the same time transmit a maximum amount of the light. It was not anticipated that such data might be useful in safeguarding life and property in the most common present-day form of amusement and entertainment. In reply to an inquiry by a manufacturer for an absorption screen to protect the moving-picture film from the intense heat of the projecting lamp, this Bureau was in a position to give intelligent advice in this matter, based upon first-hand information which, at the time it was obtained, did not appear to have any special commercial application. Many such illustrations might be given.

5. CHEMISTRY.

Standard Analyzed Samples.

There is a growing tendency in commercial and Government circles to base purchases of material on chemical analysis. Analytical operations are, however, all affected by errors, due to a variety of causes, which the utmost skill and care on the part of the operator can not altogether eliminate. By the use of certain of the Bureau's accurately analyzed standard samples, analysts may check both the correctness of the methods used by them and their skill as analysts. and, on the other hand, employers may obtain information on the character of the work done by their employes. Instructors and students in educational institutions also need aids of this kind, for otherwise neither can obtain any clear idea of the skill imparted and

acquired. Certain other samples serve as standards for the preparation of volumetric solutions or as reference standards for checking calorimetric tests of fuels and other combustible substances. The first cost of materials is often large and their preparation and analysis or purification involve much additional expense. As stock becomes depleted, it must be renewed.

However conscientiously such materials might be prepared by private concerns, the public would not place in them the confidence that is accorded to samples issued by the Bureau of Standards. The Bureau distributes these samples at approximate cost. During the past fiscal year 1,629 were called for.

A special appropriation is needed to enable the Bureau to maintain on a permanent and independent basis its series of standard samples of determined composition or high purity. Of such samples the Bureau now issues 38, and the number will increase greatly in consequence of an incessant and enlarging demand.

Determination of Carbon in Steel.

An investigation has been completed and the results published of the sources of difficulty and error in carrying out the barium carbonate titration method of determining the carbon content in steel with means for obviating these. (See Technologic Paper No. 33.)

In addition to the completed work noted above, with reference to the determination of carbon in steels, many experiments have been made to ascertain whether or not higher results for carbon are obtained by burning at temperatures much above the ordinary. Many steels do yield more carbon by a single burning at the high temperature (1,500–1,100° C.) than by a single burning at those commonly employed (1,000–1,100). The amount is always small, but of moment when an exact determination is wanted, as with the standard samples issued by the Bureau. This work has involved the designing and construction of special furnaces.

Standard Methods for the Analysis of Steel.

A committee of the American Society for Testing Materials has drafted a report of methods for the analysis of steel to be used in checking deliveries on specifications. The chairman of that committee submitted the results to the Bureau for criticism and suggestions. Considerable time was devoted to the subject, more with reference to form and uniformity of statement than to the methods themselves.

Preparation of Electrolytic Iron.

The preparation of pure electrolytic iron and of alloys of iron and carbon has been actively prosecuted throughout the year in cooperation with the division of metallurgy. A large amount of iron of satisfactory purity and several iron-carbon alloys have been prepared. Related to one phase of this problem is that of a suitable material in which to cast ingots for scientific purposes. All commercial articles tried introduced into the metal some foreign material at the high temperatures that have to be employed. Thus far magnesia specially purified has been found most suitable. In order to free it sufficiently from silica the best commercial magnesite is purified.

Influence of Gases, Oxides, and Slag on the Quality of Steel.

A most important line of research on gases, oxides, and slag in iron and steel will be taken up as soon as a suitable chemist can be found. The chemical side of this problem covers methods of analysis, but it is hoped also to make a study of the influence of gases and oxides on the physical properties of steels containing them in known amounts. This presupposes exact methods of analysis.

The determination of oxygen in steel by the Ledebur method has come into special prominence of late in connection with analysis of ingot iron. The Bureau has been urged more than once to act as umpire in fixing the content of oxygen by the method named. This it has refused to do until enough experience has been acquired to justify it in certifying to the correctness of results.

Other Investigations with Reference to Iron and Steel.

Other subjects under investigation are: The investigation of the influence of segregation on the shape and size of the test ingot used for ladle analysis at steel works; the specification and investigation of metals to be used by the United States Reclamation Service for pipes and flumes on irrigation projects in conjunction with engineers of the Reclamation Service.

Cooperation on Specifications for and Analysis of Nonferrous Metals and Alloys.

Two conferences within the year have been held at the Bureau with representatives of important scientific and technical societies to arrange for cooperation of the Bureau and committees of the several societies on the subject named above. In pursuance of a desire to avoid duplication of work by the several societies which have committees dealing with the same materials, the Institute of Metals will prepare materials for cooperative test, the American Society for Testing Materials the specifications, and the American Chemical Society will study and report methods of analysis. The Bureau will lend its aid by cooperation with the above societies in whatever direction it may be needed. A beginning has been made by taking up methods for the analysis of white metals, on a very satisfactory sample furnished by the National Lead Co.

International Cooperation on Methods of Analysis for Pig and Cast Iron.

At the request of the secretary of the American Society for Testing Materials, the Bureau has become represented on a subcommittee of the International Association for Testing Materials. To this subcommittee questions of a chemical nature relating to pig and cast iron are to be referred. The first problem before it is that of coming to agreement on the methods of sampling and analysis that shall be used for export shipments. Methods were prepared by the Bureau's representative and submitted for consideration to the members of the American committee and approved for the most part. The proposals will be sent to the British and the German representatives for consideration. The chairman of the American committee of the international association is very hopeful that these proposals will lead to a marked improvement in the existing situation as to sampling

and analyzing iron that passes from one country to another. It is desired that final agreement shall be reached so that presentation of the report can be made in 1915 at the next meeting of the International Association for Testing Materials.

Phosphate Rock Analysis and the Determination of Alumina.

A study of the analytical problems in the analysis of phosphate rock has been much interrupted by other work of pressing importance; nevertheless, progress has been made and one phase of the problem, i. e., the determination of iron, has been very satisfactorily elucidated.

Determination of Water in Standard Materials and in Coal.

Work has been done on a method for the determination of minute amounts of water in organic solids, with special application to some of the standard materials issued by the Bureau, and the study of certain methods for the determination of water in coal.

New Method for the Determination of Rubber.

This method, developed at the Bureau, consists in forming an insoluble nitrosite of rubber by the action of nitrogen trioxide gas upon a finely ground, acetone-extracted sample of the rubber suspended in chloroform. The nitrosite is filtered out, dissolved in acetone, and an aliquot portion of the acetone extract is concentrated and then distributed over alundum in a porcelain boat, using ethyl acetate to complete the transfer. After expulsion of all acetone and ethyl acetate, the residue is burned in a combustion apparatus and the resultant carbon dioxide absorbed and weighed. From the carbon found the rubber is calculated upon the assumption that the nitrosite burned contains all the carbon of the rubber. Details of the combustion apparatus and operation are given. Results on samples of known composition show the method to be fairly accurate for raw rubber and high-grade vulcanized products. (See Technologic Paper No. 35.)

The general study of methods of rubber analysis has been continued in cooperation with various committees on rubber analysis and rubber specifications, and some of the results have appeared in print.

Iodine Number of Linseed and Petroleum Oils.

The iodine value of an oil is the percentage of iodine which a unit volume of the oil will absorb. This number indicates the adulteration and may be used to determine the extent of oxidation or thickening. The iodine number has numerous very important incidental applications.

The factors known to influence the iodine number are the temperature, the time of absorption, the weight of oil taken, and the excess of iodine present obtained by increasing the amount of iodine solution. The exact effect of each factor was studied by varying one at a time.

The iodine values of raw, boiled, and burnt linseed oils, and petroleum oils, were determined by the Hanus method, varying widely the amounts of oil and iodine used, and the time of absorption. It was

shown that in order to obtain reproducible results, a prescribed procedure must be followed, and conditions stated more definitely.

Lubricating Oils.

In February a conference of lubricating-oil consumers and producers was held at the Bureau to consider questions of common interest, especially the matter of formulating suitable specifications that can be checked up by physical or chemical test. Nothing positive as to specification resulted from this conference, but several valuable suggestions were made and the initial steps were taken toward placing the specification of oil on a scientific basis. An oil engineer will be appointed during the coming year, one of whose duties shall be to look into all complaints of poor service of oils delivered under Governmental contracts in Washington, to ascertain, if possible, the reasons for poor service, whether attributable to the oil itself, or to its incorrect application, and to suggest remedial measures. It is felt that a close observation of the use of lubricating oil under different service condition in connection with laboratory investigations will lead to definite specifications and reliable tests.

Chemical Researches on Paper.

A comparison is being made of the methods of determining rosin sizing in paper, in order to devise an improved method. That used at present takes no account of nonresinous material soluble in the extraction mixture. Paper pulps and the changes which occur in ground wood pulp are being investigated with a view to ascertaining their effect on the quality of paper.

A study has been made in conjunction with the paper section of two commercial caseins, and particularly the applicability of buttermilk caseins to coated papers. This investigation was made at the request of the Agricultural Department.

Analysis of Printing Inks.

A procedure of analysis of some of the common printing inks has been adopted and is given (Technologic Paper No. 39). This is the result of the experience of the Bureau in the analysis of inks for the Government Printing Office during the past five years. It is claimed that the procedure is sufficiently accurate to determine the approximate composition of printing inks.

Hydrogen Electrode Studies.

A study is being made of the changes in acidity (hydrogen ion concentration) taking place in solutions during the course of precipitations as carried out in chemical analysis. This work is closely related to that mentioned just above, but its application reaches far beyond the specific case of phosphate rock, since it will result in placing some of the operations of chemical analysis on a scientific instead of a purely emperical basis.

Operation and Regulation of Electrotyping Baths.

The Bureau was requested by the Government Printing Office to remedy unsatisfactory working of their copper electrotyping baths.

From inquiries instituted at the Printing Office and elsewhere the need for a systematic study of the best operating conditions and the control of electrotyping baths became evident. The work done thus far has been mostly in connection with the copper baths at the Government Printing Office. Nickel baths have also been studied to some extent. This work will be continued through the coming year. In the end it will benefit not only the Government Printing Office but the whole electrotyping industry.

Physicochemical Researches on Organic Solvents.

The Bureau has in progress a number of these investigations such as the density of anhydrous ethyl alcohol obtained from different sources; the refractive indices of methyl and ethyl alcohols, their mixtures with water and each other; the density and thermal expansion of acetic acid and its mixtures with water; similarity of acetone water and glycerine water.

Other Physicochemical Researches.

Other investigations now in progress are the absolute measurement of electrolytic resistance, the mercury-cadmium cell, the critical solution temperature and its use in the determination of moisture. The latter method has been applied in the determination of the solubility of water in hydrocarbons—and equilibria in the system ammonium oxalate—oxalic acid water.

The Determination of Ammonia in Illuminating Gas.

Four common forms of apparatus and a new form designed on the principle of the Cumming wash bottle were tested. The results show that the amount of ammonia in a gas can be determined with sufficient accuracy for official or commercial testing with any of the five forms. Tests were made on different indicators and their suitability for this determination pointed out. The choice of indicator was found to be of more importance than the form of apparatus chosen. (See Technologic Paper No. 34.)

Pure Ammonia for Refrigeration Constants.

The Bureau is preparing pure ammonia and other materials used or susceptible of use (sulphur dioxide, methyl chloride, etc.) in refrigeration, with a view to the determination of their physical constants. It is also studying the nature and causes of formation of a noncondensible gas in ammonia-refrigeration systems.

Study of Gas-Testing Methods.

An investigation is in progress as to the methods for determining impurities in commercial gas, especially the methods used in municipal or State inspection work, with the object of standardizing the gas-laboratory practice of this country. A part of this research has been completed and the results have been published, covering the determination of total sulphur and of ammonia. Methods of detecting hydrogen sulphide in gas have been studied to some extent, but the work is not completed. The detection of other impurities has not yet been undertaken.

A more exhaustive study, which will extend over several years, will cover the methods and apparatus for exact and commercial gas

analysis. This study will, however, probably be preceded by the preparation of the constituents of commercial gas in a pure state. The primary object of this preparation is to determine the physical and chemical properties, especially the heats of combustion of the several pure gases, but the gases will serve also for making up mixtures of known composition on which to test methods of analysis.

A Simple Gasoline Generator for Sulphur Determination.

The generator is a simple device for saturating a current of air with gasoline vapor. The mixture of air and vapor burns readily and the flame which contains practically no sulphur is used to heat crucibles where the use of an ordinary gas flame might cause the introduction of sulphur, which is found to a considerable extent in illuminating gas. It is especially useful in determining the sulphur content of a substance.

Preparation of Secondary Butter-Color Standards.

In connection with color analysis and color standards the chemistry division developed several combinations of vaseline, wax, and paraffine which when colored were found suitable for the use of butter inspectors. It was necessary that the samples have a slightly higher melting point than butter, that they resemble butter, and that they be easily tinted to butter color.

Research on the Methods and Standards Employed in Volumetric Analysis.

Of fundamental importance for exact work in almost all lines of chemical analysis is a study of the methods and standards employed in volumertric analysis. A comprehensive scheme for such a research has been formulated and submitted for criticism and suggestion to about 150 of the most experienced chemists in this country. From the replies received it is evident that the need for such a research is widely felt and its appropriateness as a Bureau problem is admitted, although opinions differ somewhat as to what phases of the large problem should be first attacked and also as to the degree of accuracy that should be striven for.

In view of the above it is hoped that this research can be undertaken in the near future to begin with the study of acidimetry and the necessarily belated subject of indicators, and be carried out with a view to the highest practicable accuracy. However, considerable additional force and equipment will be needed before this important work can be begun.

Platinum Investigation.

It is felt that the Bureau can do much for scientific and industrial users of platinum metals and their alloys with one another. The information available is meager and manufacturers of such ware are either unable or unwilling to add to it. The work can be undertaken, however, only if a reasonably large supply of material is at hand and ample funds are available for a term of years.

The project involves the preparation of each of the platinum metals in a pure state, the study of some of their properties as metals and those of the alloys that result from their combination in varying proportions.

It is suggested that the Treasury Department might be willing to turn over to this Bureau the platinum that is saved in the refining of bullion. The cutting off of supplies of platinum from Russia renders this very desirable. Provision should be made for turning over of the crude platinum by the Bureau to makers of ware in this country for conversion into laboratory utensils as needed by the different laboratories of the Government.

Quality of Chemical Reagents.

The quality of chemical reagents on the market, especially those of high price and supposedly high purity, leaves much to be desired. It has become the practice of some of the best known dealers here and abroad to attach to the bottles carrying reagents a label setting forth the nature and amounts of the impurities in the reagents, or stating that the impurities named are not in excess of indicated percentages.

The validity of such statements depends on the accuracy and comprehensiveness with which the chemical tests that serve as a basis are made. If the statements are defective, their publication is more dangerous than the omission of all indication of the degree of purity, because of the false sense of security given the purchaser.

It has been found at the Bureau, and by many individuals elsewhere, that in very many instances the labels do not state the truth as to the contaminants mentioned on the labels and also that impurities present are not indicated. The average chemist has not the time to test his reagents accurately and in detail, even if he knows what methods to apply. It seems, therefore, that some definite and radical action should be taken to relieve the situation. A committee of the American Chemical Society endeavored some years ago, to take the quality of analytical reagents in hand, but for various reasons was unable to accomplish anything of consequence. It seems as if results of value can be secured only by the intervention of some authoritative institution, like the Bureau of Standards, in whose statement the chemical public could and would have confidence. Just what form such intervention should take is not yet clear, but possibly by controlling at the manufacturing establishments, of the bottling and sealing of each separate batch of materials, reserving a truly representative sample for analysis at the Bureau, followed by release for sale of the sealed bottles after attaching to them the test results. An alternative plan for very special reagents might be for the Bureau to purchase material at wholesale prices and to assume all the duties of bottling and sale, as it does not with most of its standards for analysis.

Either of these procedures, particularly the latter, would beyond doubt meet with the hearty approval of chemists everywhere, but would involve the creation within the chemical division of a special section, the maintenance of which would involve a considerable expenditure for salaries and purchase of materials. This expense would, however, be covered by the fees charged for inspection and analysis in the one case and derived from sales in the other.

A special function of such a section of the chemical division would be to determine the most accurate methods (with their limitations) for testing reagents and to give to these methods the widest publicity.

Oxidimetry.

It is suggested that active steps be taken to complete work already begun upon the uses of permanganate solutions in oxidimentry and especially with reference to the determination of iron. This work should be done under the direction of the associate chemists engaged in the acidimetry problem. If such plan can be actively carried out, it is believed that substantial progress can be made in the course of a few years. In the interval, up to such time as an adequate force is available, a study of the literature (a large task in itself), can be made and the details of the work planned. It is thought that the cost of apparatus and materials will not be very great.

Additional Chemical Assistance.

Attention is directed to the urgent necessity for the immediate increase of the chemical staff of the Bureau, which is at present almost entirely engaged upon the chemical work for the Bureau and the testing of materials for the Government service. The present force is entirely inadequate for these purposes. In addition the Bureau should be in a position to undertake more investigations for the purpose of determining the underlying chemical principles involved in all branches of standardization.

Chemical Tests of Materials.

More than 9,500 chemical tests of materials were made, classified by character of materials as follows: Irons and steels, 1,016; coated metals, 392; nonferrous metals and alloys, 670; materials from electrotyping baths, 250; cement materials, 958; asphalt and coal tars, 385; roofing felts, 210; linseed oils, 420; oil driers, 345; paints and paint materials, 1,022; varnishes, 400; lubricating oils, 127; greases, 14; rubber, 504; rope, 34; paper, 2,138; printing inks, 22; writing inks, 5; sealing wax, 44; molding wax, 4; flax packing, 46; asbestos, 67; roller composition, 7; wools, 85; soap and soap products, 6; glue, 5; miscellaneous, 678.

A point of interest is that the testing done for private parties is, as for last year, only about 1.5 per cent of the total. A total of 1,629 standard analyzed samples have been distributed for standardizing chemical analytical operations as follows: Samples of irons and steels, 1,300; samples of brass, 57; samples of ores, 183; samples of sodium oxalate, 89.

The Bureau's chemical tests were made for about 50 Government bureaus and establishments, including practically every executive department, as follows: Agriculture, 4; Commerce, 690; Interior, 44; Navy, 133; Post Office, 65; State, 16; Treasury, 3,864; War, 2,406; United States committees and commissions, 258; Indian establishment, 2,153; State and municipal institutions, 38; miscellaneous institutions, 10; private parties, 139.

General Paint Investigation.

Active cooperation with one of the technical societies (American Society for Testing Materials) has been in progress for several years to determine the relative value of various types of paint, both for wooden surfaces and for the protection of iron and steel.

An extensive test of white paints for wooden surface was started in August, 1912, in the vicinity of Washington. After about two years' exposure this shows that the single pigments, basic carbonate white lead, basic sulphate white lead, and zinc oxide are not in such good condition as a mixture of these pigments, and the indications are that an addition of a certain quantity of extenders, such as barium sulphate, silica, China clay, asbestine, etc., to a mixture of white lead and white zinc is an advantage.

From tests which have been conducted on steel plates painted with some 12 standard pigments and exposed to the intermittent action of water and air, commercial red lead was found to give satisfactory protection.

It is intended to confirm these general results by additional tests of those pigments which seem to warrant further investigation.

Analysis of Oil Varnish.

Considerable work has been done on investigation of methods of analysis of oil varnishes, and while progress has been made the methods which have yielded promising results are very long and tedious, and publication has been deferred pending experiments which it is hoped will yield more rapid and equally accurate results.

Corrosion of Iron and Steel.

Though much study and many tests have been made in an effort to determine what type of metal is most resistant to corrosion, the results so far obtained are conflicting, and the user of the material is at a loss how to specify the most resistant metal.

The bureau is taking an active part in planning an extended series of service tests in cooperation with a committee of the American Society for Testing Materials, composed of manufacturers and consumers of the types of ferrous metals in commercial use, which it is believed will furnish valuable information. In addition to this series of tests it is the intention to conduct an independent set of tests on similar types of metal, entirely under the control of the bureau, as so many factors enter into this problem that no one set of results can be considered conclusive.

6. METALLURGY.

The Critical Temperatures A2 and A3 of Pure Iron.

An important scientific investigation of fundamental interest in defining the properties of iron and steel, completed last fall, is the determination of the critical temperatures A2 and A3 of pure iron. The existence and nature of the lower transformation, A2, had been in dispute for over 25 years, and the interpretation of the properties of iron in an uncertain condition. With specially designed apparatus using pure iron from several sources, including samples made at the Bureau of a purity of 99.98 per cent and freed from gases, A2 was exactly located at 768° C., and A3 at 909° C. in heating and 898° C. on cooling. No other critical ranges were found for pure iron below 1,100° C. This investigation called forth the following action by the

American Institute of Mining Engineers at the October meeting in 1913:

Recognizing that the work being accomplished by the United States Bureau of Standards is of great value, not only to the scientific but also to the commercial interests of our country, the persons present at this meeting of the American Institute of Mining Engineers, held in New York this 17th day of October, under the auspices of the iron and steel committee of said institute, most earnestly urge upon the proper National Government committees and authorities the supreme importance of proper financial and other support to that bureau, and also request that allied and kindred American scientific and commercial organizations also act in this matter in such ways as in their judgment seem best advised.

The results of this work were also received favorably by the British Iron and Steel Institute.

Finishing Temperatures of Rails.

A matter of the greatest importance to the public is the production of sound rails. One of the questions involved in their manufacture about which there are differences of expert opinion is the temperature at which rails should be rolled. In order to determine what is the American practice and to demonstrate the practicability of accurately gauging temperatures in a steel mill, an investigation has been carried out on the finishing temperatures and properties of rails. The Bureau has had the hearty cooperation of four of the principal rolling mills of the country, their plants being placed at our disposal for this investigation. It was found that the mills roll their rails at temperatures well within the specifications, but that the latter permit finishing temperatures to be higher than those of the ingots from which the rails are rolled. This specification, which is supposed to limit rail finishing temperatures to a point slightly above the "critical range" of steel (about 670° C.), has therefore no significance. There were also determined the expansion coefficients of Bessemer and open-hearth steels, 0.0000146 and 0.0000156, respectively, per degree C. between 0 and 1,000° C.; the melting ranges of rail steels, 1,470 to 1,525° C.; their critical ranges, below which it is not safe to roll rails, 650 to 680° C. on cooling; and the distribution of temperature throughout a rail section on cooling from 1,070° C., showing variation of over 80° C. from center to surface.

Melting Points of the Elements.

Among the fundamental constants that enter into many physical and chemical relations of the elements are their melting points. There has been completed a determination of the melting points of the chemical elements of atomic weight 49 to 58, using in part the method of the micropyrometer which permits accurate measurements with samples as minute as 0.001 mg. The following results were obtained for melting points: Nickel 1,452° C., cobalt 1,478, iron 1,530, manganese 1,260, chromium 1,520, vanadium 1,720, titanium 1,795. In this investigation the Bureau had the cooperation of several chemists both in the United States and abroad who furnished very pure samples of the elements they had prepared.

Total Radiation from Nickel Oxide.

The application of scientific methods to metallurgical and other technical processes carried out at high temperatures, necessitates the

introduction of methods of measuring these temperatures and requires, for this purpose oftentimes, a knowledge of the characteristic radiation or emissivity of heated substances both throughout the visible spectrum and for the total radiation. Experimental methods have been devised which are of general application and an investigation completed on the spectral and total radiation of nickel oxide in the range 600° C. to 1,300° C. The corrections to pyrometers using a single colored light and using total radiation have also been determined when sighted on heated nickel oxide. The monochromatic emissivity was found to increase linearly with increasing wave length between 0.5 and 0.7μ and to decrease linearly with increasing temperature. The total radiation increases with temperature. The following table gives some of the results obtained:

Value of monochromatic emissivity of nickel oxide for:

Wave length						0.5	0.6	0.7μ
For T=1,060° C. Eλ=						.88	.885	.89
Temperature	800	900	1,000	1,100	1,200	1,300° C.		
(Wave length=0.65μ) Eλ=	.96	.93+	.91	.89	.87	.85—		
Correction to optical pyrometer (using λ=0.65μ) for above temperatures	+2	+4	+7	+10	+87	+20		

Value of total radiation for:

Temperature °C	600	800	1,000	1,200	1,300
Total radiation (E)	0.54	0.68	0.76	0.85	0.87
Corrections to add to radiation pyrometer	110	95	75	55	45

Iron-Carbon Equilibrium Diagram.

The fundamental problems in the scientific metallurgy of iron and steel is the establishment of the "iron-carbon equilibrium diagram" which gives the temperatures at which transformations take place in iron and steel. This has been studied by numerous investigators, but there are still many outstanding discrepancies and uncertainties due to several reasons, such as unreliable temperature scales and inaccurate methods of measuring temperatures, impurities both solid and gaseous in the samples experimented upon, uncorrected factors such as rates of heating and cooling, etc.

An experimental investigation of the iron-carbon system by thermal methods is well under way, making use of the methods and apparatus for determining the critical ranges of pure iron. It is hoped to finish this work the coming year for the temperature range 0° to 1,100° C. for all possible compositions of the iron-carbon alloys and using only strictly pure materials.

Besides its purely scientific interest, the interpretation of the iron-carbon diagram affords a basis for the rational heat treatment of steels, a question of the utmost practical importance.

It is planned to study in detail the exact effect on the iron-carbon equilibrium of the addition of other elements such as manganese, silicon, etc., using alloys of exactly controlled composition.

Preparation of Pure Metals and Alloys.

The preparation of strictly pure metals and alloys is absolutely essential as a basis for providing suitable materials for the scientific study of the properties of such metals and alloys, and often these very pure standard materials are not readily obtainable and sometimes

not available at all. The Bureau therefore has begun the preparation of certain pure metals and alloys. The purest iron yet obtained was prepared at the Bureau by an electrolytic method and then melting in vacuo; this iron has been used in the determination of the critical ranges of pure iron by thermal analysis and by electrical resistance and as the basal material for making up a very complete series of the pure iron-carbon alloys. The preparation of irons. steels, nickel and other pure metals and alloys of the iron group will be continued on a more extended scale and with the endeavor to produce larger pure samples than has been hitherto possible, for the purpose of studying the physical properties of such pure metals and alloys.

Carbon in Steels at High Temperatures.

A more strictly chemical problem, but of very considerable metallurgical interest, is the determination of carbon in steels at high temperatures and the variation with temperature and with other constituents. A preliminary account of such an investigation giving the accuracy to be expected under certain definite conditions of experiment is in press.

Material for Crucibles.

The most troublesome factor in the preparation of pure irons and steels is the securing of suitable crucible materials which will not contaminate the metals during the melting process. A very small amount of silicon, for example, present in a magnesia crucible will contaminate iron and its alloys, thus vitiating the purity sought. A thorough investigation of the methods of preparing inert crucibles free from such impurities is being carried out and satisfactory small magnesia crucibles have been made. New methods have been devised and are being tested for purifying magnesia on a scale suitable for crucibles for the melting of larger samples, and other refractory materials are also being experimented with.

Physical Properties of Pure Iron.

The study of the physical properties and allotropy of pure iron is being continued by an investigation, about completed, on the electrical resistance and critical ranges of pure iron from 0° to 950° C. It is shown that there are no anomalies or transformations in iron below 757° C. (=A2) the temperature at which the electrical resistance shows a reversible inflexion, i. e., the same on heating as on cooling. At the upper critical range (A3) there is a transformation beginning at 894° C. on heating and cooling and extending over 25° C. in each case, acompanied on heating by an actual decrease of resistance on cooling through A3. A precision of 1 in 1,000,000 was attained in the measuremnets of the iron resistance, and a new cooling-curve method was used. This work will be extended to the iron carbon and other iron alloys and it is also planned to investigate the thermoelectric behavior of iron and its alloys over the same temperature range. This work with that on the thermal behavior, will then form a rational experimental basis for an adequate theory of the allotropy of iron and for the explanation of the iron-carbon diagram as based on the variation in the several physical properties.

Standard Test Specimens.

The American Institute of Metals has been desirous of obtaining authoritative data on the best forms and methods of preparing standard test specimens of nonferrous alloys and particularly of the more ordinary bronzes and brasses. The Bureau, with their cooperation, has been carrying out an experimental investigation on standard test specimens of the zinc bronze: 2 zinc, 10 tin, 88 copper. The effect on the physical properties of pouring temperatures and methods of molding and casting have been studied as well as of the best shape of test pieces and of heat treatment such as annealing and quenching together with microscopic examination of the structure of the metal and determination of its transformation temperature. This investigation is to be extended to other bronzes and brasses as facilities permit.

Causes of Failure of Railway Material.

The Bureau is charged with the investigation of the causes of failure of railway material. The prevalence of such failures and their disastrous consequences need no comment. As a preliminary to this investigation, with the cooperation of the Department of State there has been secured considerable information concerning European regulations and specifications regarding the manufacture and use of railway material and statistics of railway accidents and failures. Numerous conferences have been held with representatives of railroads, manufacturers of railway material and representatives of technical societies responsible for specifications, with a view to planning this investigation to best serve the public, and various manufacturing plants have been visited. These have offered all possible facilities for aiding in this work.

In addition to the investigation completed on finishing temperatures and properties of rails, a beginning has also been made on an experimental study of what has recently become one of the most serious and puzzling causes of failure of rails, known as transverse fissures. The Bureau has been asked for help in this matter by the Public Service Commission of New York State, has already the active cooperation of one of the large railway systems, and the offer of cooperation from one of the rail mills. The Bureau will undoubtedly be aided by all interested parties. The investigation of failed rails which have caused accidents and submitted by the Interstate Commerce Commission for examination, has recently been put on a systematic basis by the addition of special equipment and the arrangement for a more efficient cooperation of the several divisions of the Bureau interested.

The various factors entering into the processes of manufacture of and specifications for rails should be taken up, such, for example, as determining the effects of rolling rails of different kinds hot and cold. This will require the active cooperation of rail mills and railways. Through the generosity of Sir Robert Hadfield, who placed nine ingots made by various processes including his own at our disposal, it has been possible to commence a far-reaching study of sound ingots and rails.

It is planned to make a thorough study of the metallurgical, chemical, and mechanical problems of car wheels including specifications,

tests, foundry practice and of the different classes of service on railways.

Fusible Boiler Plugs.

A fusible boiler plug which had failed to operate, causing a boiler explosion and loss of life, was submitted for test by the Steamboat-Inspection Service. The tin plug was found to be converted mostly into oxide. A systematic investigation of fusible boiler plugs has been begun including an examination of new plugs for fulfillment of specifications, and of used plugs to determine their deterioration. Experiments are also being made on the production of tin oxide from tin in presence of steam which already indicate that the oxidization of the tin can be greatly accelerated. The durability of fusible tin plugs would therefore appear to be a serious question. This investigation is of considerable extent, involving the examination of the properties of several hundred plugs.

Failure of Manganese Bronze.

Another type of failure of nonferrous metals has been brought to the attention of the Bureau by the board of water supply of the city of New York, namely, the failures of "manganese bronze" and other brasses used in the construction of the Catskill aqueduct. These serious failures appear to be due to faulty methods of manufacture and the Bureau is beginning an experimental investigation of these metals in the light of the above experience with a view to determining the procedure necessary to prevent such failures and for the purpose of developing adequate testing methods to detect faulty metals of this class.

Thermoelectric Method of Determining the Impurities in Platinum.

In exact chemical combustions in which platinum crucibles are used there is loss of weight of the crucible which limits the accuracy of these operations. It appeared to the American Chemical Society highly desirable to make exact measurements of the loss in weight of various grades of platinum ware on heating and to determine the composition with least loss. An extended series of such experiments are being carried out particularly with reference to the effect of iridium and iron as impurities on loss of weight. A thermoelectric method of determining the impurities in platinum in terms of iridium has been developed which permits accurate certification of the platinum content without destroying or even defacing the objects tested. This method of detecting platinum purity has already been of service to several Government bureaus, institutions, and firms in the selection of platinum utensils and will probably become of general application. Many persons interested have taken the opportunity offered by the Bureau to have the purity of their platinum ware tested here by the thermoelectric method. Some experiments with crucibles containing rhodium show this metal to be preferable to crucibles containing iridium or even to pure platinum crucibles.

Nomenclature of Alloys.

Attention has recently been directed to the unsatisfactory status of the nomenclature of alloys. This question has been taken up by

the Bureau in connection with committees of the American technical societies interested and with the International Journal of Metallography. There are prospects of obtaining a very considerable improvement in a most desired uniformity of usage in the naming of metallic alloys.

Measurements with the Micropyrometer.

Measurements with the micropyrometer are being carried out on several problems. This instrument permits the measurement of temperature of microscopic particles (0.001 mg.) to 3,000° C. and there is in preparation a series of determinations of the melting points of some 15 of the refractory chemical elements. Most of these can be obtained pure only in minute quantities and the method of the micropyrometer is the only one available for the determination of this important constant for some of these elements. We have here the cooperation of many chemists who have supplied samples of pure chemical elements.

It has also been possible to apply the micropyrometer to the measurement of the monochromatic emissivity of microscopic samples. This constant has been determined for some 20 elements. It is expected to determine the melting points and emissivities of all the available refractory elements and of numerous oxides. The melting points of several hundred commercial steels are also being determined by this method.

Method of Sampling Steel.

A matter in which there has been lack of uniformity of practice in steel works is the method of sampling the method for analysis. In cooperation with a committee of the American Society for Testing Materials the Bureau has taken the preliminary steps in an investigation of test ingots including a study of the segregation of the chemical elements as determined chemically and microscopically in terms of size and shape of the ingot with the object of determining the best size and shape of the ingot and method of taking the sample. This work should be followed by an experimental comparison between ingot analyses and those of the finished product, as in many instances, very embarrassing anomalies have been found. It is probable that for some products, such as rails, it will be found advisable to specify the analysis of the finished product rather than of a sample ladled out of the liquid metal before casting.

Efficiency of Surface Combustion Furnace.

There is also under way an investigation of the efficiency of a surface combustion furnace. This is a new type of gas furnace which gives very high temperatures with less fuel than the usual forms.

Metallurgical Testing.

The following metallurgical tests were completed: There were submitted 198 samples for test involving heat treatment and thermal analysis, of which 4 were of nonferrous metals and 194 of iron and steel; 126 samples were submitted for metallographic testing, of which 4 involved rail failures, 70 were for identification of metals or process of manufacture, 13 involved metal failures, and 39 samples were for miscellaneous metallographic testing; and 22

samples were submitted involving miscellaneous metallurgical testing.

Of these 346 test items, 201 were for 12 different establishments of the Government and 45 for the public, or 82 per cent of testing was for the Government. The Government tests were distributed among the following: Springfield Armory, Geological Survey, Interstate Commerce Commission, Isthmian Canal Commission, Bureau of Standards, Secretary of Commerce, Bureau of Navigation, Post Office Department, District of Columbia, Quartermaster Department, Public Printer, and the Steamboat-Inspection Service.

Several of the above tests were of an elaborate nature requiring extended experimental investigation and some of them required as well thorough bibliographic studies. There has also been heavy correspondence on specifications for and properties of metals.

Metallurgical Information.

Requests for information on the metallurgical properties of metals and alloys have come from most varied sources, including Government bureaus, electrical companies, railroads, technical societies, universities, students, jewelers, inventors, metal manufacturers of all kinds, patent attorneys, consulting engineers, State governments, public-service commissions, city governments, automobile manufacturers, etc.

From the many letters received on the subject there appears to be a general demand for United States standard specifications and definitions of metals and alloys of all kinds, and surprise is sometimes expressed that the Bureau of Standards has not a complete file of such specifications.

The requests, verbal and written, for information concerning properties of metals cover almost every conceivable aspect of the subject and the information furnished finds its way into many channels, such as preparation of specifications, improvement of manufacturing processes, products and instruments, textbooks, detection of fraud or impurities, explanation of failures, patent litigation, etc. The following are a few illustrations, many of which might be given:

Regarding contamination of nickel by salt for use as to constancy of melting point of salt in nickel crucibles for thermoelectric calibration.

What is wrought iron?

Metals which expand most and disintegrate least on heating.

Latent heat of fusion of copper, from a technical handbook author.

Several requests as to patinas of different metals, from jewelers and others.

How to prevent corrosion of iron and steel pipes, posts, etc., from several Government departments and others.

Definition of bronze and brass, etc.

Melting points of many metals, from many classes of people.

Relation of heat treatment to change in dimensions, from manufacturers of automobile parts.

How to make a copper-titanium alloy.

How to recover lead from used storage batteries, from Navy Department.

How to detect a mechanical, electrical or chemical break in copper wire, from consulting electrical engineer.

Publications.

In addition to the above questions upon which information was furnished, the Bureau issued during the year the following metal-

lurgical publications: "Metallographic testing" (Circular No. 42); "The critical ranges A2 and A3 of pure iron" (Scientific Paper No. 213); "Melting points of the refractory elements, 1—Elements of atomic weight 48 to 59" (Scientific Paper No. 205). The following publications are now in press: "Observations on finishing temperatures and properties of rails," "The determination of carbon in steel and irons by direct combustion in oxygen at high temperatures," "The emissivity of metals and oxides. I—Nickel oxide in the range 600 to 1,300."

7. STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

Structural Steel Column Tests.

An important investigation, now in progress, which is of great value to the engineering and architectural professions, consists of series of column tests which the Bureau is now 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 nine different types of cross sections. Eighteen columns of each type are being tested, nine of light and nine of heavier structural shapes. The nine columns, both of the light and heavy kind, are made in these different lengths, so that there are three columns of each type and weight of section having the same length.

The American Railway Engineering Society's columns comprise 18 latticed columns provided with square bearing plates at both ends. For the present only one type of cross section, but of two different weights of structural shapes, has been used. Both the light and heavy columns are made in three different lengths, there being three columns of each length and weight of cross section.

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 sized columns have not been available heretofore.

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, i. e., to make a minimum amount of material carry a given load with safety.

The testing of these columns must be done very carefully in order to secure reliable results. About one-third of the two series of columns have been tested since the beginning of these tests last December. The work has not progressed far enough to admit of drawing any definite conclusions from the tests, and it may be necessary to considerably extend the present program of the investigation before arriving at a final interpretation of the results.

Brick and Concrete Column Tests.

The tests of a series of full-sized concrete columns have been made on the 10,000,000-pound testing machine at the Pittsburgh branch. These columns were designed and constructed under the supervision of a committee of practical engineers in order that they might represent as nearly as possible the actual conditions found in concrete work. The results of this investigation, as well as that of a similar investigation as to the strength of brick piers will be of great value to architects and construction engineers.

Failure of Rails and Railway Material.

At the request of and in cooperation with the division of safety appliances of the Interstate Commerce Commission, the Bureau has conducted investigations to determine the causes of rail and tire failures, all of which caused derailments or wrecks. Similar material is also being collected directly from the railroad companies and manufacturers of railway equipment. In each case careful chemical, microscopic and mechanical tests are made to ascertain whether the metal is of inferior quality, or whether the present day service conditions as to wheel loads are too severe or too great. The results of this investigation will contribute toward safer railroad communication.

Standard Test Specimen for Cast Bronze.

At the request of the American Institute of Metals, the Bureau has undertaken the investigations preliminary to the establishment of a standard test specimen for cast bronze. About 800 specimens have been prepared from a typical bronze consisting of 88 per cent copper, 10 per cent tin, 2 per cent zinc, and tested for ultimate strength. It is hoped that these results in conjunction with the results of the investigation of the metallurgical division will serve as a guide in the specification of a standard test specimen for such materials. (See also Metallurgical investigations.)

Influence of Time in Testing Steel Specimens.

The Bureau is cooperating with the American Society for Testing Materials in an investigation to determine the effect of the speed of application of the load on the yield point of a steel specimen in tensile tests. 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. The work has only recently been undertaken and no analysis of any of the results have yet been made.

Measurement of Strains in Engineering Structures by Means of the Strain Gauge.

Some time ago the Bureau began an investigation of the measurement of strains in engineering structures by means of the strain gauge. The method was employed on typical bridges, structural steel buildings, boilers, canal lock gates, and ships, for the purpose of ascertaining whether or not the method is applicable for the measurement of stresses in such structures. Considerable data in connection with these typical cases have been collected, but owing to the

recent transfer of the expert engaged in this work to the Interstate Commerce Commission, the publication of the results of this investigation has been delayed.

Wire Cables.

An extensive investigation of causes of failure of wire hoisting cables has been planned and begun, and steps are being taken toward the collection of material. This investigation is being carried on at the Pittsburgh branch, and will cover the various practical uses of these cables about which very little is known at present.

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 the testing of machines up to 50,000 pounds capacity and has undertaken the design and construction of an 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.

Information as to the Strength of Metals and 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 alloys. These inquiries were received from universities, research laboratories, individuals, corporations, and the various branches of the Government service.

The inquiries covered a wide range of subjects. Many were requests for technologic papers and other printed matter; others pertained to standard specifications and standard methods of testing and some asked for the strength of different articles such as ropes and knots, chains, wires, riveted joints, brass tubing, etc. The Bureau's opinion has been sought in regard to the accuracy of various testing apparatus; also in regard to the feasibility of various devices and structures such as concrete ties and new types of rail. Inquiries have been made concerning the kinds of testing apparatus needed for particular purposes and concerning the usefulness of new apparatus. Information as to the cause of failure of manufactured materials has been the basis of many requests.

The information given by the Bureau has been used in selecting the proper equipment for laboratories, in legal cases, in the testing of supplies, and in the design of various structures.

Tests on the Strength of Materials.

The tests of compression and tensile strength and transverse bending strength made at the Washington laboratories were for practically all departments of the Government. They included 275 iron and steel tests; such as reinforcing bars, Army-tent tripod, boiler plate, button head bolts, boiler flues, twisted type stay bolts, wire stay bolts, steel anchor bolt, a large number of cast-iron arbitration bars; 48 tests of copper, and brass and other alloys; 10 cable and rope tests; and 18 miscellaneous.

In addition, two Riehle testing machines, one of 200,000 pounds and the other of 400,000 pounds capacity, have been calibrated to 50,000 pounds, at the request of the steel company owning them.

Hydration of Portland Cement.

One of the most interesting investigations completed during the past year has been one dealing with the hydration of Portland cement. This study is of prime importance, both to the manufacturer and consumer, since if it were shown that the presence of any one constituent in Portland cement would give very desirable properties in particular cases, such as quick hardening or slow hardening, the manufacturer could so control his product that he could obtain either of the above desired properties. At the same time the consumer who might desire either of these, depending upon the conditions, would be able to secure them in the market. Furthermore, the conditions under which concrete is hardened vary to a great degree; also the medium in which the concrete is hardened varies considerably. If, therefore, in a study of hydration, the products which result under normal conditions were determined, it would be possible to anticipate what would result under abnormal conditions of hardening. This present investigation showed what the production of hydration of the constituents of Portland cement are under normal conditions, and also which of the constituents produced the early hardening and which the later hardening.

The above investigation was carried on at the Pittsburgh branch with materials produced in an electric furnace and with some commercial cements, but in no case were the actual products of hydration compared with the strengths produced. At the present time, however, this investigation is being continued with materials prepared in sufficient quantity to make specimens for physical testing, and the results so far obtained on these confirm the results obtained in the above-mentioned investigation. The burning of Portland cement in which the various constituents have been carried through wide limits, has been continued, as well as an investigation in which the effect of replacing the lime with magnesia has been studied. In the latter case cement has been burned in which no limestone has been used in the raw mix, it having been replaced entirely by dolomite. The results obtained in all the burns have been very interesting, but it has not been thought advisable to publish them until some long time tests have been completed.

Durability of Concrete in Alkali Waters.

One of the most important investigations started during the year is being 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 waters. This is, in fact, an extension of an investigation started by the Government in 1908, a report of which was published in Technologic Paper No. 12 of the Bureau. Some 8,000 specially prepared experimental drain tile were made under the Bureau's supervision and shipped to badly alkaline districts in Colorado, Montana, Wyoming, Arizona, Washington, New Mexico, Utah, where

typical alkalies having different characteristics were found, and to Missouri, Minnesota, and Iowa, for comparative purposes. These tile were installed on Government reclamation projects under expert supervision and are to be inspected and tested from year to year. The results of this investigation will be of much value to the public and the Government in irrigated districts of the West where concrete is the most available structural material and will be most economical for certain purposes if it will resist alkali disintegration. The people of the West have been somewhat skeptical concerning the permanency of concrete exposed to alkali waters owing to the failure of a number of Government and private structures in such districts.

High-Pressure Steam Test of Cement.

The investigation of the value of atmospheric and high-pressure steam tests as a means of determining the soundness of Portland cements has been continued. Results indicate that this test can not be used as a reliable guide. Many cements failing to pass this test are, under normal conditions, found to be sound and equal in cementing value to those which do pass it. This test has been exploited during the past few years by some engineers and widely discussed in the technical press. Many requests were received by the Bureau for information concerning the merits of the test and it was on this account that the investigation was started. A report giving results of tests of concretes up to two years of age made with these various cements will be published during the ensuing year.

Methods of Determining the Time of Setting of Cement.

An investigation was completed which showed the sources of error in determining the time of setting of cements by the Gillmore and Vicat needles. This was undertaken because of a controversy between the engineering societies and the Government as to the relative merits of these apparatus. Neither apparatus was found to be satisfactory and the Government's contention was supported that both methods are subject to about the same error and the simpler should be adopted as standard until a more satisfactory method can be developed. The determination of the time of setting of cements is important. If a cement sets too rapidly, it may harden before it is placed in the forms; and if it hardens too slowly, it causes added expense in handling.

Standard Cement Sieves.

The importance of standard cement-testing sieves to the industries was pertinently brought to the attention of the Bureau by the fact that one cement mill had to regrind thousands of barrels of cement, at considerable financial loss, on account of unknown variations in the standard sieves which they were using to standardize their product. An investigation of "Variations in the results of sieving with standard cement sieves" was completed during the year and published as Technologic Paper No. 29. A further investigation of the standard 200-mesh sieves was made and completed, but it has not yet been published. The results of this investigation suggest the desirability of changing the specifications for standard sieves and the necessity of ensuring to the public a standard sample for checking sieves. It shows that the uniformity of sieves should be much

improved, as the greatest variation is in the spacing of the warp wires which are fixed by the accuracy of the reeds, upon which wires are threaded when the cloth is woven.

Standard Specification for Portland Cement.

Joint meetings with representatives of other Government departments have been held with representatives of the American Society of Civil Engineers and the American Society for Testing Materials in an endeavor to obtain one United States standard specification for Portland cement. These meetings have been productive of suggested improvements to all present specifications and substantial agreement has been reached on a single specification in all but a few matters, and it is believed all differences will be adjusted before the end of the ensuing year. The work of this conference made necessary several investigations of testing methods and has suggested the inadequacy of present tests and the need of much additional work of this character. The endeavors of this conference which is fixing the standard of quality for all American Portland cements affects the entire industry and assists the engineers by furnishing them an adequate and practical specification.

Miscellaneous Investigations of Stone, Cement, etc.

The miscellaneous investigations have included the investigation of marbles considered for use in the construction of the Lincoln Memorial; of floor marbles and composition flooring materials, such as magnesite, cork, rubber, cement, etc.; of marbles for toilet rooms to determine their suitability for Government buildings; the cause of defects and failure of concrete and composition floors in Government buildings; the suitability of sands for use in concrete; the cause of defects in plaster wall; the suitability of certain available materials in reclamation projects for the production of silica cements, etc. Many of these investigations required several weeks' or months' work while others were completed within a few days. A total of 538 samples of stone and 138 samples of miscellaneous materials were tested in connection with these investigations. A very few tests of cement, concrete, and stones were made for city and State governments, commercial testing laboratories, cement manufacturers, stone quarries and the public, mostly in connection with investigations or as check tests. Samples of cement were tested for a cement manufacturer to determine the relative quality of the product from his various mills. Samples of concrete were tested for a city which suspected that a contractor had supplied inferior concrete. Samples of stone were tested for a State government and for the public to determine physical qualities.

Investigation of Building Stones.

An advisory committee, composed of representatives from the United States Geological Survey, Office of Public Roads, Bureau of Mines, and the Bureau of Standards, was organized to obtain cooperation in a comprehensive field and laboratory investigation of the stone resources of the United States. In the past each Bureau has been working in its own particular field and there was no correlation in the work. Thus, where geologic data were often available concerning structural stones, the physical qualities were not known

or the reverse condition existed. Also, there has been more or less duplication of work. A general agreement as to distribution of work, in order to avoid any duplication, was reached and a program outlined. Some new stone working equipment has been purchased for preparing samples and work will start with the beginning of the ensuing fiscal year. It is proposed that the Bureau maintain a sample file of the building stones of the United States which will be available for reference to the Government and public, together with information on the physical qualities.

Effect of Moisture and Temperature Changes on Concrete.

Work was continued on a study of the volumetric changes which take place in concrete and the behavior of concrete exposed to various moisture and temperature conditions. Special study has been made of concrete in street pavements, as the information is necessary to properly design this type of structure, and prevent subsequent cracking. The results of this investigation are of interest more particularly to the highway and general construction engineer. There are so many variables entering into this problem that it will probably require several years to obtain satisfactory results.

Granular Analysis of Cement.

The development of a granulometric analyzer was completed and studies have been made of the fineness of about 25 brands of cement. The results indicate that the quantity of active cementing material in Portland cements can be more readily determined by an apparatus of this type than by the use of sieves. A quantitative separator has also been designed which is capable of selecting the particles of various sizes and will permit of a study being made of the value of fine grinding of Portland cements and its effect on quality. The results of this investigation will be of particular value to such Government offices as the Reclamation Service, and is of much general interest to the manufacturer and consumer of cement. If it is found that only the "flour," which comprises about 35 per cent of the cement, is appreciably active, considerable saving could be made by separating this material at the point of manufacture and not paying freight on a very large quantity of relatively inert material.

Durability of Plasters and Stuccos.

An advisory committee, consisting of representatives from the Government, engineering societies, the Lime Manufacturers Association, Cement Manufacturers Association, Gypsum Industries Association, and Metal Lath Industries Association, was organized to assist in a comprehensive investigation of the durability of stuccos and plasters. A preliminary investigation was started by the Bureau two years ago and the present program is an extension of that work. The work is just inaugurated and no results are yet obtainable. The investigation was deemed necessary on account of a number of failures which have occurred in Government buildings, the inquiries received by the Bureau for information concerning methods of preventing the cracking of stucco, the durability of various kinds of metal lath, the cause of discoloration of plasters, the proper mixtures to be used, etc., and the general lack of reliable information

in this field. This investigation will extend over a number of years and involves both laboratory and field work.

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, and collating information on the condition of concrete structures exposed to sea water in various ports of the world. 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.

Silica Cements.

The study of sand or silica cements has been continued and a report giving two years' results will be prepared during the ensuing year. The Reclamation Service are now using this type of cement on some of their western projects and the investigation was made with their cooperation. As the cost of silica cements is only about 60 per cent of that of Portland cements, if they are found to have comparable cementing value, they would greatly reduce the cost of concrete structures. The cooperation of the War Department was also obtained in connection with this investigation, as they had used some silica cements in 1899 and 1900.

Results of Specification Tests of Portland Cement.

A collation of all specification tests of Portland cements made by the Government laboratories since 1901 is being prepared for publication. Such a report will be of general interest to the manufacturer and consumer of cement giving as it does the chemical composition and physical qualities of about 90 per cent of the American brands.

Variation of the Physical Properties of Concrete.

A study of several thousand compression tests is being made of concrete which was fabricated and exposed in various ways. It will be shown by this study what precautions are necessary in the fabrication of concrete to ensure a product of known quality. This will be of interest to all consumers of cement. The Bureau is constantly receiving inquiries concerning concrete, the elements of which will be discussed in this paper.

Cement Inspection and Testing.

Cement was inspected during the year at 13 different cement mills located in Virginia, Maryland, Pennsylvania, New Jersey, New York, Ohio, Indiana, Kentucky, and Kansas. The inspection work included the taking of samples, their testing, and the subsequent inspection of packing and shipping. A total of 7,610 samples were tested for the Navy and War Departments, Bureau of Lighthouses, Isthmian Canal Commission, Supervising Architect's Office, District of Columbia, Lincoln Memorial Commission, etc. Inspection was

made of 599,400 barrels of cement for shipment to Panama and 148,385 barrels for shipment to Government departments in the United States, for use in the construction of Federal buildings, river and harbor improvements, etc. The testing of cement at the Pittsburgh branch has also been for Government bureaus, particularly the United States Army Engineers. The necessity for this inspecting and testing of cement is well illustrated by the fact that out of 265,518 barrels sampled, 32,200 barrels have been rejected. In addition 4,200 barrels have been withdrawn by the manufacturer, since he recognized the inferiority of the material he submitted before we were ready to start our tests. This cement has been submitted by plants as distant from Pittsburgh as Kentucky and Indiana.

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, 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, design of concrete piles for use in sea water, durability of composition magnesite floors, the physical properties of stones, the cause of failure of drain tile, etc.

From cement manufacturers, architectural stone manufacturers, commercial testing laboratories, requests were received for information on the accuracy of sieves, the physical properties of concrete, the value of fine grinding, the value of silica cements, cause of failure of drain tile, effect of sewage combined with sea water on concrete, the value of high pressure steam tests, methods of testing materials, cause of shrinkage of architectural stone, the interpretation of cement specifications, etc.

Investigation of Paving Blocks.

A study of the toughness of paving blocks which have been taken from pavements of various ages in 12 cities was made. The method of construction, wear, and condition were noted, and the resistance of the blocks of abrasion determined by means of the standard rattler. Blocks of medium toughness and strength were found to give satisfactory service if put down well, viz, with good concrete foundation, uniform and well-rolled sand bed, and good grouting. The better the quality of the blocks, the less sensitive the pavement will be to defects in construction.

Study of White-Ware Glazes.

A study has been carried on of glazes for white ware and vitreous pottery, free from lead oxide. A well-fused glaze of good appear-

ance was found but it possesses certain disadvantages which have been pointed out.

Behavior of Clay in Water Suspension.

The behavior of clay in water suspension under the influence of a direct current was observed. It was shown that the attraction of the clay by the positive electrode was a factor in the purification process only when iron is present in the granular form, viz, as pyrite, siderite, etc. Clay containing colloidal ferric oxide is not freed from the latter. The main factor in the elimination of ferruginous impurities is the preliminary process of deflocculation by means of caustic soda, sodium oxalate, or tannic acid. The electrical conductivity of clays with varying water content was studied.

Viscosity of Porcelain at Kiln Temperatures.

The viscosity (tendency to soften) of a series of porcelains at kiln temperatures was determined. It was found that the viscosity increased rapidly with the kaolin content. The present American porcelains are working with too low a clay substance content. By raising the proportion from 44 to 50 per cent, better standing up qualities are obtained.

Plasticity of Clays.

Three sections of an investigation dealing with the plasticity of clay have been completed, one dealing with the compression, tensile and transverse strengths of clays in the dried state, one with the flow of clay under pressure through an orifice, and one with the critical study of the method proposed by Atterberg for the estimation of plasticity. The work upon the plasticity of clays is being continued with special reference to methods of measurement. This problem is a very difficult one whose solution appears to be in the accurate study of the mechanical properties of clays in the plastic state with particular reference to deformation and flow under pressure.

An extensive research is under way, relating to the effect of dissolves salts upon clay suspensions. This work has special significance, owing to the fact that application is made of these phenomena in the industries, especially the manufacture of sanitary ware and pottery, in which hand molding is being replaced by the casting process. The principles underlying the changes brought about by the addition of small quantities of salts are not of a simple nature. The work carried out so far shows the injurious influence of clays carrying soluble sulphates, like the ball clays, and the surprising effect of air entrapped by the clay substance. The benefits obtained by the exhaustion of air from the suspension have been brought out.

Suitability of American Clays for Vitreous Ware.

Several series of investigations are being carried out in connection with the study of porcelain, having in mind, first, the most feasible combination of American clays for the production of vitreous dinner ware; second, the most practicable composition of chemical porcelain, made entirely if possible from American materials. The chemical porcelain used in this country has so far been imported and with the great demand for this kind of product, it seems very

necessary that the establishment of this industry be encouraged. Such problems as the determination of translucency are coincident with the first part of this investigation, dealing with vitreous table ware. The comparison between American and European kaolins and ball clays is an essential part of this work.

Ceramic Glazes.

Considerable work is being done in connection with ceramic glazes. The most urgent problems are being selected, such as the production of a cheap, one fire enamel, to be used in the manufacture of enameled brick and tile. A collection is being made of glazes and enamels, for all kinds of products which have proven useful, for later publication. The study of cast iron enamels, possessing maximum resistance to the action of acids, is contemplated for the coming year. Crystalline glazes of the zinc silicate type are being prepared for microscopic study by the petrographer.

Drying Properties of Clays.

Physical studies are being made of the drying of clays by means of a specially designed oven in which the critical points during this process are being observed. The effect of small additions of electrolytes are also being studied in this connection. A study is being made of the effect of the size of grain upon the drying and the vitrification of shales.

Clay-Shrinkage Disks.

A system of clay-shrinkage disks, which are used largely by pottery manufacturers for the control of their kilns, has been correlated with the temperatures to which the shrinkages indicated by the standard gauge correspond.

Production of Paving Bricks from Slag.

The work upon the production of paving blocks from fused slag is being continued. The results previously obtained in small laboratory furnaces are now to be utilized in actually making slag blocks of practically commercial size by the use of a sufficiently large furnace.

Strength of Refractory Bodies.

A research is to be begun dealing with the study of the strongest refractory bodies subjected to compression at temperatures from 1,300° to 1,400° C. Owing to the heavy losses caused in the ceramic and other industries by the breakage of saggers, glass pots, supports, etc., this problem is of considerable practical importance. Part of this work will embrace the comparison of American and European bond clays for the purpose of eliminating the latter if possible. At present considerable amounts of these materials are being imported.

Effect of Crystalline Salts upon the Structure of Clay Products.

The effect of crystalline salts upon the structure of clay products is to be studied in a series of tests. This work was begun during the past year and it was shown by the destructive effect of such salts as sodium sulphate, sodium thiosulphate, magnesium sulphate, and sodium chloride that a well-defined limit existed between clay ware

standing up or failing under this treatment. Clay burnt below 950° C. failed without exception. It is hoped that a test will be developed which will tell quickly whether a product will prove durable under weather conditions or not.

Investigation of Building Tile.

A building-tile investigation is under way. Data collected has largely been along the line of determination of proper loading for building inspectors. This is to be followed by tests to determine bearing power and properties of tile walls, in relation to brick and other material, fireproofing qualities, etc.

Resisting Power of Earth.

An investigation has been authorized for the determination of the properties of earths in relation to sustaining power of piles, foundations, effect of moisture, viscosity effects on time rate of depression under loads, standardization of soils for the structural purposes of engineering, etc. This investigation is in cooperation with the committee of the American Society of Civil Engineers.

Strength of Brick Piers.

A brick-pier investigation has been under way for some time which will be representative of the bricks manufactured east of the Mississippi, covering four principal geographical centers of manufacture. A study is being made of bonds, comparative strength of mortars, qualities and properties of brick, both individually and collectively, in piers of various heights. The members are of a size commensurate with those in practice.

Composition of Window Glass.

An investigation has been started concerning the limits of the composition of window glass, with reference to the magnesia content, and with reference to the content of alumina. In the literature on glass many contradictory statements are made concerning these two constituents, and it is hoped that the facts may be brought out.

Testing of Clay Products.

The testing done by the clay products section for the Government, especially the Isthmian Canal Commission, consisted of 250 physical tests. In addition clay testing was done for the United States Geological Survey, covered by the time of one man for three months. These tests referred to samples of fire clay collected by the Survey in eastern Pennsylvania and Maryland. Considerable time was spent in the preparation of a technical report on the white-ware pottery industry for the Bureau of Foreign and Domestic Commerce. Cooperative tests are also under way for the Geological Survey of Florida.

A considerable number of tests, approximately 160, were made for the public, usually free of charge, and comprised preliminary tests of clay as well as special tests and inquiries pertaining to defects and manufacturing troubles. In addition, 157 tests were made for the public for which fees were required. The correspondence with manu-

facturers of ceramic products has been very heavy. In many instances manufacturers have called at the ceramic laboratory with specimens of the raw materials or finished products. In unusual cases trips have been made to the plants at the expense of the manufacturers.

Cooperation with Technical Societies.

The Bureau cooperates also with educational institutions and technical organizations by contributing papers and articles to their transactions, and taking part in their discussions. Such cooperation is being carried on with the American Ceramic Society, the American Society for Testing Materials, the National Brick Manufacturers' Association, the National Paving Brick Manufacturers' Association, and a number of State organizations.

Sand Lime Brick.

The action of CO_2 when introduced into the hardening cylinder during the manufacture of sand lime brick, has been found to give a product having a compressive strength about 50 per cent higher than brick produced without the CO_2. This should enable the manufacturers of sand lime brick to improve the quality of their product, with little extra expense, and should therefore be advantageous to the users of brick, or the general public.

Strength of Lime Mortars.

Measurements of the various strengths of lime mortars show, first, that these strengths are generally low, and second, that laboratory measurements are not reliable. These results are negative only, but should prove of interest to architects and engineers. The shearing strength of a lime mortar is somewhat less than its compressive strength. The area in shear should be about one and one-half times the area in compression, in order to measure the shearing strength.

Properties of Lime.

A method has been developed by means of which it is possible to tell beforehand whether or not a lime plaster will "pop" or "pit" on the wall; that is, whether small particles will fall out and leave pin holes. This test should be valuable to lime manufacturers, plasterers, and owners, by eliminating, or at least fixing the responsibility for, "popping."

It has been found that hydrated lime spoils by air-slaking quite rapidly when stored in the ordinary commercial packages. This fact is of especial interest to the dealer and the small user.

The quantity of sulphur in a lime bears a certain general ratio to the amount originally present in the stone plus that in the fuel used to burn the lime. This is of importance to the lime manufacturer because the presence of sulphur is frequently the cause of inferior quality of the lime.

The amount of carbon dioxide in a lime (which is indicative of the amount of air-slaking) can be determined rapidly and with fair accuracy by titration, using phenacetolin as an indicator. This method is not scientific, but can be used for plant control by the manufacturer, or for inspection by the user.

Effect of Temperature During the Hydration of Lime.

When lime is slaked there is a tendency toward local overheating of the material with the production of "lime which has been burned during hydration." It is believed that the presence of this material is the cause of popping, and also of the lack of plasticity in some commercial hydrates. An attempt is being made to find out what this material is, how it is formed, how its formation can be prevented, or how the effects of it can be nullified. Its isolation has not been accomplished as yet. The material is believed to be formed whenever the temperature in any part of the mass of lime and water is permitted to exceed 350° C.

Plasticity of Lime.

Whenever lime is used for masonry or plastering purposes its use depends primarily on its plasticity, or working quality. This property must therefore be included in any rational specification for lime. The development of a test for plasticity has been carried out along lines suggested in Merriman's "Mechanics of Materials," and the test is now being applied to commercial hydrates of known working qualities, in order to determine its value. It is believed that the plasticity of hydrated lime depends to some extent on the size of grain of the material. Commercial hydrates have been separated into grains of different size by elutriation (water flotation), but this question can not be finally answered until the method of measuring plasticity is fully developed.

Use of Lime in Portland Cement Mortar.

It has been found that as much as 25 per cent hydrated lime can be used in a Portland cement mortar without material diminution of strength, whether the lime is magnesian or high calcium, and whether the mortar is permitted to set in the air or under water. These conclusions are based on tests of specimens 1 year old. Specimens have been made up to be tested when 2 and 5 years old.

Properties of Gypsum.

An investigation is being made of the physical, chemical, and optical properties of gypsum, which has been calcined at different temperatures, in an attempt to throw some light on the behavior of some of these products which at present appear inexplicable.

Lime Testing.

The commercial testing of lime done by the Bureau has been very limited, and is confined almost exclusively to locating the cause of an inferior quality of product, at the request of manufacturers.

Information as to Lime and Its Products.

Requests for information come mainly from present manufacturers in regard to quality of product; prospective manufacturers, in regard to plant equipment; and users who wish to know the location of the nearest producer and the quality of his product. Under users is included a large number of inquiries about the properties of sand lime brick. The National Lime Manufacturers Association and

the American Society for Testing Materials have committees which are attempting to write specifications for lime. The Bureau is cooperating with both of these committees.

Textile Investigations.

Owing to the large amount of textile testing done for the Government in connection with the purchase of textiles, and the adoption of the new tariff schedule, it has been impossible to take up any new investigational work, some of which is very badly needed in connection with the improvement of the methods of testing textiles and their specification. A few of the most urgent are as follows: (1) The moisture content of cotton, wool, silk, and linen yarns and fabrics at various atmospheric conditions. (2) The correctness of worsted yarn numbers, the percentage of oil present, and the tensile strength of those sizes of yarns having a large consumption. Many mills have furnished yarns for this investigation but we have been unable to proceed with this work. (3) The effect of twist upon the tensile strength of cotton, wool, and linen yarns and the amount of twist that will give the maximum tensile strength. (4) The cotton spool-thread investigation. (5) The development of better methods of testing and cooperating with the textile trade relative to adopting standard methods for tests. (6) The quantity of sizing and loading material in cotton cloth and its effect upon the strength of the fabric. Strength of various sizes of yarns should be a valuable one for our yarn manufacturers, buyers, sellers, and the textile trade in general. (7) The effect of humidity upon cotton and wool cloth relative to weight and tensile strength. (8) Investigation of adulterated textile articles now upon the market. There is complaint by consumers everywhere that textiles are misbranded and misrepresented by the mills producing them, by the middlemen and by those selling them over the counter in stores.

Shrinkage of Wools.

By shrinkage is meant the total loss of weight in raw wool, due to the removal of all grease, dirt, or other foreign matter. This information is needed by wool growers, manufacturers, commission merchants, and especially by those interested in the question of placing the testing and sampling of wool on a more scientific basis.

This investigation was made (1) to obtain some definite knowledge as to the shrinkage of some of the foreign raw wools imported into this country, (2) to ascertain the shrinkage variation in two samplings of the same fleece, and (3) the difference in shrinkage between two fleeces of the same breed of sheep. There were 49 fleeces experimented upon, and the shrinkages ranged from 19.5 to 54 per cent, i. e., the yield of clean wool was from 80.5 to 46 per cent, according to the breed of the sheep. In the South Australian wools the greatest shrinkage difference between two determinations upon the samples drawn in the same manner from the same fleece was 3 per cent, while for the New Zealand wools the largest difference was 6 per cent. The differences were calculated on the basis of raw wool weight. The difference in shrinkage between two fleeces of the same breed of sheep grown in the same location was found to be as great as 9.5 per cent.

Information as to Textiles.

The Bureau is assisting the Department of Agriculture in determining the maximum temperature Egyptian cotton fiber can be heated without causing deterioration to its strength. This information is desired in connection with an extended investigation by that Department of the injurious effect of the pink boll worm (an insect very injurious to cotton fiber) found in imported Egyptian cotton.

The Bureau has published for distribution Technologic Paper No. 19, on "The physical properties of cotton yarns," also Circular No. 41, which gives a general outline of textile analyses performed by the Bureau, drawing attention to particular conditions and methods of test that should be followed, precautions to be exercised, rates of charges, etc. This circular has served in a very large way to educate the textile trade along the lines of more scientific buying and selling of textiles.

During the year the Bureau tested over 2,400 samples of textiles, mostly of materials purchased by the Government. These included cotton, silk, and linen cloths, spool thread, tracing cloth, areoplane cloth, automobile-tire fabric, sail cloth, canvas, tent cloth, table linens, artificial silks, wool cloth adulterated with cotton, cordage, etc.

The Bureau was called upon as referee in a controversy between a cotton mill and a consumer of large quantities of automobile-tire fabric. Tests were made upon samples of fabric.

The textile section of the Bureau has assisted in the drafting of textile specifications, particularly for Government purchases, and to some extent for the public. It has rendered valuable assistance in court cases, and assisted various committees. The Bureau cooperated with the Bureau of Foreign and Domestic Commerce in the testing of domestic and foreign-made jute bagging for cotton. This work was of considerable value and the results were published by that Bureau in a pamphlet entitled "Cotton bagging and ties," October 20, 1913.

A special report was made to the Ways and Means Committee, House of Representatives, relative to methods of testing cotton cloth for duty assessments under the new tariff law.

The Customs Service at the Appraisers Stores, New York, were furnished a short and accurate method of determining the yarn number upon imported cotton, wool, silk, and linen yarns.

A complete revision of the textile specifications of the material purchased on the "General supply schedule" was furnished to that committee. The Bureau drafted specifications for the purchase of textiles required by the Office of Indian Affairs, Department of the Interior. In the case of both offices mentioned above the textile section tested the bidder's samples and assisted in the making of all awards for contracts for the fiscal year ending June 30, 1915.

At the request of the Treasury Department, a representative of this Bureau visited the New York Appraiser's Stores, made a report of the textile work there, and suggested more efficient methods of appraising importations.

The War and Navy Departments were assisted in their textile specifications and in the matter of testing various materials under dispute.

Several bills before Congress relating to the enactment of a "pure-fabric law" were submitted to the Bureau for criticisms and suggestions.

Paper Investigations.

A study of the causes of deterioration of paper for permanent records has been undertaken and will be advanced as fast as possible. The results of such a study will be of utmost importance to the general public.

The question of the influence of atmospheric moisture on paper during the process of color printing has been suggested by lithographers and printers as a problem of great importance to the printing industry. Work along this line has been started.

The investigation on butermilk caseins and its application to the paper industry for sizing and coating paper, is well under way. The results obtained so far indicate that buttermilk caseins will have almost as large a field of usefulness as skim-milk caseins. To facilitate this investigation the Bureau has installed a complete machine for coating paper. Cooperative work with mills making coated paper is in progress, and one mill has given assurance that it will assist the Bureau to make the final determinations on a commercial scale. This mill has already given much valuable assistance. The final results of this investigation will be of value to the dairy, paper, paste, and other industries using casein. Buttermilk, now a waste product, may be turned into a new source of supply for usable casein, and at the same time lower the cost of casein to the industries.

The past year's work of the paper laboratory has clearly demonstrated that investigation work has been seriously handicapped, due to the large amount of routine work required by the departments and the small laboratory force available for this work.

Paper Conference.

The second annual conference between paper manufacturers, commercial testing laboratories, and this Bureau was held at the Bureau of Standards. This conference has resulted in establishing a closer spirit of interest and cooperation between the parties concerned and has enabled this Bureau to present the Government paper requirements to the manufacturers. These conferences will be held annually and for the purpose of affording an opportunity for discussions along technical lines relating to the paper industry. This annual yearly conference will result advantageously to the entire paper industry, as well as the public.

Paper Testing.

During the past year the Bureau has tested the following samples of paper: For all Government departments, 2,749 samples; for public and private interests, 242 samples; total number of samples tested, 2,991. These tests were made for practically all departments of the Government, the Government Printing Office, and other establishments. This large amount of routine work has made it almost impossible to give much attention to those investigations which have been undertaken.

Information as to Paper.

In addition to the routine testing of paper purchased by the executive departments, they have been given every possible assistance both in the preparing of paper specifications and in securing papers best suited to their particular needs. Such assistance has enabled the Government to substitute lower priced paper for the higher grades, and in a few instances it has been pointed out that a higher grade ought to be used. The question of chart paper for the United States Coast and Geodetic Survey has received considerable attention, and it is believed that the investigations along this line will result in securing a chart paper of higher quality.

The circular on paper and paper testing is nearly completed. It will enable the small user to more correctly judge a paper for a particular use.

Suggestions have been received from a number of paper companies that this Bureau take up the standardization of paper and paper testing not only as applied to Government purchases, but also as applied to the entire paper industry. Such standardization would be of great importance and benefit to both manufacturers and consumers of paper. This work should be undertaken by the Bureau.

Hack-Saw Blades.

An investigation to determine the relative efficiency of different makes of hack-saw blades has been in progress for more than a year. This work was undertaken at the request of the Government and a committee of manufacturers of hack-saw blades. The results thus far obtained indicate that the specifications in general use are inadequate to determine the wearing quality of blades. The work, which has been subjected to numerous interruptions, will be pushed as rapidly as possible with the view of developing reliable tests and specifications.

Properties of Rubber.

A study of the physical properties of rubber, with special attention to the influence of temperature on these properties, has been continued during the past year. In conducting this work practically all of the apparatus and testing machines have been designed and constructed at the Bureau. The results of many tests that have been made, both on routine samples and on samples secured for experimental work, will be used in revising Circular No. 38, which illustrates and describes the apparatus and methods employed in testing rubber at the Bureau. This circular is now in its second edition and the demand for it is steadily increasing.

An experimental rubber mixing and vulcanizing plant has been installed, and is now ready for operation. This plant will be of great value to the Bureau in preparing samples of definite composition which will be used for experimental work both in the physical and chemical laboratories. The Bureau has already rendered valuable assistance both to manufacturers and consumers in improving existing methods of testing and in designing special apparatus to expedite and facilitate the various tests.

In addition to the many tests of rubber made for Government departments, the Bureau has cooperated with technical societies and with manufacturers in developing specifications and methods of testing. Numerous requests have been received for working drawings of the testing machines that have been developed at the Bureau, and in every case the desired information has been supplied. A number of these machines have been adopted by the leading rubber manufacturers of the country and by some of the largest testing laboratories engaged in the testing of mechanical rubber goods.

Tests of Miscellaneous Materials.

A total of 1,347 samples of miscellaneous materials, principally for Government departments, were tested during the year. These included 200 samples of rubber hose, 644 samples of packing (rubber asbestos, etc.), 45 samples of rubber bands, 69 samples of rubber covered wire, 135 samples of asbestos gaskets, 41 samples of leather belting, 71 samples of rope, 28 samples of hacksaw blades, and others.

8. ENGINEERING RESEARCH AND TESTING.

Applications of the Dimensional Method to Physical Problems.

An investigation of the dimensional method of attacking physical problems is under way. The "Principle of dynamical similarity," necessary in the interpretation of experiments on mechanical models (ships, aeroplanes, etc.) is the most familiar instance of the application of this method; but the importance of the method is much greater, especially in technical physics, and its applicability far wider than has commonly been recognized. A general and fully illustrated exposition of the subject is in preparation, several preliminary papers dealing with special chapters having already been published in scientific and technical journals.

Windage Resistance of Steam Turbines.

A general equation was deduced from the theory of dimensions, which is shown to agree with such experimental data on windage as have been published. The data at present available are not adequate as a basis for the computation of windage corrections, except in a few simple cases. (See Scientific Paper No. 208.) The data are analyzed and suggestions offered as to practical computations. By applying the principle of dynamical similarity, it is shown that model experiments may be utilized and the practicability of such experiments is discussed.

The problem is an important one in turbine design and operation.

Water-Current Meters.

During the past year 266 calibrations of current meters, used for the measurement of the velocity of flow of water in streams, open channels and ocean currents, were made by the Bureau for the United States Geological Survey, Reclamation Service, and other Government departments, State governments, and engineers in private practice.

The number of instruments submitted for test showed an increase of 33 per cent over the previous year.

To provide better conditions for the routine rating of these important instruments and facilities for a comprehensive investigation of the characteristics of the different types, a concrete tank 400 feet in length has been constructed and special apparatus for automatically recording data has been designed. The new station will be in operation early in the next fiscal year.

Anemometers.

Within the last year or two there have been frequent requests for information relative to the use of anemometers of the vane type for the measurement of air velocities encountered in fan, ventilating, and similar work. These instruments are distinct from those used for meteorological measurements. Requests have been made for tests as high as 10,000 feet per minute. The Bureau is unable to make these tests or supply the information requested. An investigation to determine what instruments are suitable for this service, their characteristics, and the best method of calibration, would furnish data which is greatly needed by engineers in this field.

Gasoline Engines.

The Bureau has installed a gasoline-engine testing plant for determining the power and fuel consumption, at various speeds, of motors such as are used in automobiles, motor boats, and aeroplanes. Preliminary tests were made on two Renault aeroplane motors for the United States Signal Corps.

This apparatus was installed by and is to be used in cooperation with the Signal Corps, in order to furnish reliable means for testing such motors as they might acquire or contemplate purchasing.

Vacuum Traps.

A request was received from the Supervising Architect of the Treasury Department for data to be used in the preparation of specifications for purchase of vacuum traps used in the steam-heating systems of Government buildings. Special apparatus has been constructed for this purpose, and an investigation of the operation under working conditions of some 18 different makes of traps is now in progress.

Hose Couplings.

The great benefits that would result from a standardization of fire-hose couplings has long been recognized, and lack of uniformity in this respect has been responsible for great loss of life and property in certain large conflagrations, such as the Baltimore fire in 1904, when fire engines sent from other cities in response to calls for aid were unable to render assistance for the reason that their hose couplings, being of different design, would not couple up with the local fire-hose connections.

This Bureau has for a number of years been in cooperation with leading fire-protection organizations of the country with the view of establishing a standard fire-hose coupling. As a result of this cooperation, a large number of cities and the leading fire-protection associations have adopted a standard design known as the national standard fire-hose coupling. In order to render this important move-

ment as far-reaching as possible, the Bureau of Standards has prepared a circular outlining the history of the undertaking and setting forth the advantages to be derived from the general adoption of the standard coupling.

Miscellaneous Instruments and Devices.

As a result of tests completed by this Bureau during the past year for the Treasury Department, portable vacuum cleaners supplied to that department for use in public buildings under its control are now purchased under specifications, by the provisions of which the efficiency and effectiveness in operation of these machines may be determined and compared by simple tests.

In addition to the rating of current meters, 145 tests of other instruments were made, including steam, vacuum and hydraulic gauges, water meters, fire extinguishers, valves, vacuum cleaners, dynamometers, paper tester, and miscellaneous devices.

Facilities Needed for Engineering Research.

The large and steadily increasing demands made upon the Bureau for routine tests of this nature render it impossible, with the present working force, to make satisfactory progress in the several lines of investigation that have been undertaken. There are many important engineering researches that should be undertaken and perhaps no greater assistance could be given both the Government service and the manufacturing interests of the country than by the development of adequate facilities for such researches. The Bureau's work in this field has scarcely begun and is limited almost exclusively to a few of the more pressing cases of the Government service.

III. OFFICE, AND ENGINEERING AND CONSTRUCTION.

1. OFFICE.

Publications.

During the past year the Bureau issued four numbers of the Bulletin of the Bureau of Standards, completing the tenth volume of the bulletin; 23 scientific papers; 11 technologic papers; 5 circulars; and 2 miscellaneous publications, a total for the year of 41 Bureau publications.

The following new circulars were issued during the year: "Metallographic testing," "The metric carat," "Polarimetry," "The testing of materials," and "The testing of barometers."

The following scientific papers were issued: "New calorimetric resistance thermometers," "The silver voltameter—Part III, second series of quantitative experiments and the preparation and testing of silver nitrate," "Note on cold-junction corrections for thermocouples," "The analysis of alternating-current waves by the method of Fourier, with special reference to methods of facilitating the computations," "The constants of spectral radiation of a uniformly heated inclosure, or so-called black body, I," "Melting points of the refractory elements; I, Elements of atomic weight from 48 to 59," "High-frequency ammeters," "A comparative study of American direct-current watthour meters," "Windage resistance of steam-turbine wheels," "Latent heat of fusion of ice," "Observations on ocean

temperatures in the vicinity of icebergs and in other parts of the ocean," "Accuracy of the formulas for the ratio, regulation, and phase angle of transformers," "Melting points of some refractory oxides," "Critical ranges A2 and A3 of pure iron," "Note on the setting of a mercury surface to a required height," "Micrometer microscopes," "The pentane lamp as a working standard," "Testing potential transformers," "Comparison of the silver and iodine voltameters and the determination of the faraday," "Production of temperature uniformity in an electric furnace," "The silver voltameter—Part IV, third series of quantitative experiments and special investigations," and "Flame standards in photometry."

The following technologic papers were issued: "Surface insulation of pipes," "Electrolysis in concrete," "Electrolytic corrosion of iron in soils," "Special studies in electrolysis mitigation, I, a preliminary study of conditions in Springfield, Ohio, with recommendations for mitigation and control," "Variations in results of sieving with standard cement sieves," "The viscosity of porcelain bodies," "Some leadless borosilicate glazes maturing at about 1,100° C.," "Special studies in electrolysis mitigation, No. 2, electrolysis from electric railway currents and its prevention—an experimental test on a system of insulated negative feeders in St. Louis," "Determination of carbon in steel and iron by the barium carbonate titration method," "Determination of ammonia in illuminating gas," and "Combustion method for the direct determination of rubber."

The following miscellaneous publications were issued: "Annual report of the Director for the fiscal year ended June 30, 1913," and "Eighth annual conference on the weights and measures of the United States."

In this connection it should be stated that the length of time required to print the scientific and technical papers of the Bureau often necessitates preliminary announcements through the technical press instead of by Government publication. This is to be regretted, and it is hoped that more prompt methods may be found to eliminate all possible causes of delay. The decrease in the Department's allotment for printing may hamper the Bureau in new publication and keeping in stock publications required in the ordinary conduct of its business.

Delays occur in the present indirect method of forwarding franks to the Superintendent of Documents. As the Bureau is located at a distance from the city, the franks addressed at the Bureau should be sent by messenger direct to the Printing Office. The documents, it is believed, could then be mailed the same day when necessary, or in emergencies the messenger could assist in inclosing them. At present, the Bureau can not remedy the delay which in many cases is a week or more. The urgent reason for a more direct system is that in many cases the publications should really be sent as inclosures in letters, since they are intended as a part of the reply giving information desired.

Library.

The Bureau maintains a working library of reference and current periodicals on subjects directly connected with the Bureau's work. It contains nearly 12,000 volumes related to its work. Those

engaged in research and investigation work must have available the reference works required for consultation without overcrowding the library with books which may be borrowed from other scientific libraries of the city. The cooperation of such libraries in the loan of books, developed during the past few years, has proved to be of great assistance in scientific work.

Correspondence.

A large amount of technical correspondence in addition to the necessary routine connected with tests and the business administration of the Bureau requires a competent force of clerks. In the file rooms approximately 55,000 letters were handled during the year. The files are by subject and are indexed by card catalogue. The vertical files of the unit system have been in use since the Bureau was established and have been found very convenient. The increase of about 40 per cent in the amount of correspondence over the previous year has taxed the force required to handle it. Assistance will be required to do the work efficiently.

Storeroom.

In the storeroom is centralized the purchase of standard stock and supplies and the care and record of property. The property record is maintained as a card catalogue, classified by serial number assigned when equipment is received at the Bureau. A duplicate card is classified according to the nature of the equipment. A record is also maintained classified by divisions to which the equipment is assigned. The inventory property of the Bureau now includes, approximately, 50,000 items, a large portion of which includes scientific apparatus. With the growth of the equipment and the increasing work connected with property records, it is necessary that a high-grade clerk be provided to serve as a property clerk for this equipment.

Personnel.

During the year the Bureau staff comprised 230 statutory appointees, and about 107 engaged in researches and investigations specially authorized by Congress. The statutory positions included 144 scientific positions, 29 office assistants, 33 engaged in the operation of the plant, and 23 in the construction. There were 446 personnel changes during the year. These included 105 separations from the Bureau, of which 38 were resignations. In the consideration of civil-service certificates, it may be of interest to note that 62 eligibles declined appointment, 11 of whom declined after acceptance and appointment.

The work of appointments is greatly embarrassed by the difficulty of securing suitable eligibles for many of the places, also by the delay usually from one to three weeks in receiving certificates after making request.

The routine connected with personnel actions is also involved, new appointments, for example, requiring about 30 distinct steps in the ordinary course.

Appropriations and Accounts.

With the responsibility resting on the Bureau to audit accounts prior to payment, the labor of examining accounts has increased.

The volume of Bureau accounting has increased threefold during the past few years. A much closer accounting system has been adopted, which permits systematic summaries showing the itemized detail for each class of expenditure and for each appropriation by administration divisions of the Bureau. The system and form of statement were developed at the Bureau and is believed to be in many respects the simplest and most complete statement of Bureau expenditures which has ever been in use. The design and installation of dispatch boards covering the various branches of the work of the office has distinctly aided the Bureau in keeping track of its routine work. While it can not prevent delays due to lack of assistance, the system has made it possible to keep the closest track of outstanding work and schedule business.

Attached hereto are tables showing the amount and object of each outstanding appropriation, together with the disbursement and balances up to June 30, 1914. The first statements cover the appropriations for the fiscal year ended on that date. The second table covers the outstanding disbursement and adjustments on account of the appropriations for the fiscal year 1912 and 1913, respectively.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1914, 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, 1914:

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$290,940.00	$258,528.85	$11,595.03	$20,816.12
Equipment	60,075.00	56,132.40	3,854.49	88.11
General expenses	25,200.00	19,357.52	4,788.13	1,054.35
Grounds	3,000.00	2,888.27	111.73	.....
Testing structural materials	75,000.00	69,961.65	4,991.35	47.00
Testing machines	30,000.00	24,204.20	5,777.23	18.57
High potential	15,000.00	13,757.64	1,214.85	27.51
Refrigeration constants	15,000.00	11,434.63	3,552.99	12.38
Testing railroad scales	25,000.00	18,573.23	6,389.92	36.85
Fire-resisting properties	25,000.00	9,404.45	15,047.73	547.82
Warehouse and storehouse	45,000.00	18,623.39	24,226.99	2,149.62
Tank	5,000.00	4,964.05	31.50	4.45
Equipment, electrical laboratory	25,000.00	24,942.38	50.43	7.19
Laboratory	200,000.00	197,356.50	1,594.44	1,049.06
Total	839,215.00	730,129.16	83,226.81	25,859.03

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1914:

Appropriation.	1912			
	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$236,340.00	$224,050.96	.....	$12,289.04
Equipment	52,027.50	50,586.89	$1,188.94	251.67
General expenses	25,702.77	25,320.03	47.35	335.39
Grounds	3,000.00	2,892.93	.....	107.07
Testing structural materials	78,533.50	77,988.62	248.62	296.26
Testing machines	30,000.00	29,793.92	.....	206.08
Investigating effects of electric currents	15,000.00	14,877.31	3.65	119.04
Total	440,603.77	425,510.66	1,488.56	13,604.55

Appropriation.	1913			
	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$241.312.66	$226,682.95	.....	$14,629.71
Equipment	51,000.00	49,462.50	$1,156.45	381.05
General expenses	23,200.00	22,701.09	182.90	316.01
Grounds	3,000.00	2,986.81	.....	13.19
Testing structural materials	77,342.50	77,045.29	47.99	249.22
Testing machines	30,000.00	29,839.03	2.10	158.87
Investigating effects of electric currents	10,000.00	9,919.63	7.50	72.87
Refrigeration constants	15,000.00	14,597.86	390.10	12.04
Total	450,855.16	433,235.16	1,787.04	15,832.96

Summary of Tests and Fees.

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. Much of it involves investigation of the scientific principles underlying the test, a study of existing methods, and the development of new standard tests of known accuracy. For the test a reasonable fee is charged, except when made for the National or State Governments.

During the fiscal year 1914 the Bureau made 107,741 tests and inspected 1,078,127 incandescent lamps at various factories for other departments of the Government. Of the total tests 96,687 were for the Government, and 11,054 for the public. The testing was distributed as follows, according to nature of tests: Length measures, 612; mass, 61,176; capacity, 4,000; temperature, 11,010; hydrometry, 1,207; miscellaneous, 74; optical, 1,475; electrical, 724; photometry, 1,883; chemical, 10,543; engineering (miscellaneous), 1,440; engineering (instruments), 277; structural materials, 8,706; paper and textiles, 4,614. The estimated fees amount to $127,413, of which $12,989 were 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.

2. ENGINEERING AND CONSTRUCTION.

Mechanical Plant.

Since the original installation of the heating and power plant of the Bureau, three large laboratories have been added and a fourth is in process of construction. During this time such special additions have been made to the Bureau plant as space permitted. However, the plant is not only being used to its full capacity, but at certain seasons of the year is greatly overtaxed. It is evident that the completion of the chemical laboratory authorized at the last session of 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.

Provision should also be made for the better handling of the mail and express between the Bureau and the city, by the addition of a small auto delivery wagon. The collection of samples of materials to be tested for the various Government bureaus and the delivery of results have been seriously retarded by the lack of such conveyance. This is often a serious matter in connection with the award of contracts or the acceptance of deliveries.

The personnel of the engineering division should be augmented by providing an additional assistant engineer, a fireman, and a laborer.

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 steamfitting, electrical wiring, wood working, 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 due in part to insufficient janitor service and in part to the lack of continuous supervision of that service. It is hoped that the janitor service may be increased during the coming year and that provision may be made for its proper supervision.

The care of the grounds has become of sufficient importance to warrant the continuous employment of a foreman. The funds available for the care of the grounds have been insufficient to do any grading or to begin the construction of permanent roads. This will be partially taken care of during the coming year.

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. The late Alfred Noble, one of the most prominent engineers that America has produced, made the following statement concerning the necessity for the construction of such a machine:

> The use of steel and concrete in girders in the construction of bridges and buildings is increasing rapidly. The calculations of strength of such girders are to a large extent based on theory, not well checked by actual tests; such tests as have been made were on small girders, and the value of the results in determining the dimensions of large girders such as are now in common use is doubtful. It is questionable whether, on the one hand, many structures in daily use are not perilously near the breaking point; or, on the other hand, whether the structures are not built unnecessarily massive and costly.
>
> There is therefore great need of a large testing machine for actually testing the strength of girders of large size. Such a machine, operated under the direction of the Bureau of Standards, would soon repay its cost by inducing more economical and safer construction.

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 scientific principles involved. Several departments of the Government are deeply interested in maintaining this method of communication on the best possible basis. To do this they will each be compelled not only to keep in close touch with the progress of other countries in this respect, but to undertake such scientific and technical investigations as may be necessary. 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, and another of $10,000 to enable the Bureau of Standards to carry on that part of the radio work which naturally falls to the Bureau in connection with the radio supervision work of the Department of Commerce, was included in the estimate for the current year, but were not appropriated for. It is recommended that they be again submitted in the estimate for the next fiscal year.

Additional Ground.

The recent opening of Van Ness Street north of the Bureau at a place not adjoining the Bureau's grounds, make it necessary to secure the small strip of land between that street and the north boundary of the Bureau site. Efforts were made without avail to secure the location of the street in a position adjoining the Bureau's property. It is also advisable to secure the narrow strip between the Bureau and Tilden Street on the south.

Additional Scientific Assistance of the Minor Grades.

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 considerably increased.

Increase of Funds for Special Investigations.

Several of the special funds under which the Bureau is carrying on important work should be increased, namely, structural materials, testing and inspection of large scales, the public-utility fund, and that for the investigation of the fire-resisting properties of materials, and for the investigation of the causes of failure of railway materials.

Standard Materials.

In another part of this report attention is called to the necessity of extending the preparation of standard samples of materials. The Bureau is unable at present to prepare more than a few of the most important. These samples are in great demand by a large number of industries, as well as educational institutions. A special appropriation of not less than $4,000 should be asked for to provide for the preparation of these samples. It should be kept in mind that these samples are distributed at the cost of production, the greater part of the expense of their preparation being returned to the Treasury.

Investigation of Textiles, Paper, Leather, and Rubber.

The increased tendency on the part of the Government and the public to purchase textiles, paper, leather, and rubber according to specifications and tests, makes it necessary for the Bureau to develop standards of quality and methods of testing. This is especially important in view of the fact that laws and regulations are rapidly being prepared and enacted regarding the branding and quality of these materials, both of which involve standards and methods of testing. An item should therefore be included in the next estimates to cover this work.

Investigation of Clay Products.

The pottery, brick, tile, terra cotta, and other industries engaged in the production of clay products are greatly in need of reliable and authoritative data concerning the properties of these products and the materials which enter into them. In few industries is there any greater opportunity of the improvement by the application of precise measurements and of scientific knowledge of the nature of the products. For this purpose it is recommended that a special fund of $10,000 be included in the estimates.

Color Standards and Specifications.

The industries engaged in the manufacture of paper, textiles, dairy products, oils, dyes, inks, and many others, are in urgent need of such standards and the methods for their use. A special fund of not less than $5,000 per year for three or four years would enable the Bureau to take up the more important phases of color work.

Covering for Meter-Testing Tank.

The meter testing tank as constructed is in the open and is not available for use in the winter or bad weather. These and other conditions make it desirable to inclose it by a light inexpensive covering which will protect it and make it available in all kinds of weather.

Repairs and Alterations.

The funds available for repairs and alterations should be increased for repainting the walls of three of the larger buildings, together with the external woodwork.

Respectfully,

S. W. STRATTON, *Director.*

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

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