

# Annual Report

of the

## Director of the Bureau of Standards

to the

### Secretary of Commerce and Labor

for the

Fiscal Year Ended June 30, 1912



WASHINGTON  
GOVERNMENT PRINTING OFFICE  
1913



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DEPARTMENT OF COMMERCE AND LABOR,  
BUREAU OF STANDARDS,  
*Washington, July 1, 1912.*

SIR: I have the honor to submit the following report of the work of the Bureau of Standards for the fiscal year ended June 30, 1912.

At no time has the Bureau had so many demands for its cooperation in regard to industrial standards, in devising standard methods of measurement and test, and in researches involving precise measurement. The Bureau has continued with gratifying results its policy of cooperation with all technical interests concerned. A few actual cases will illustrate the cooperation which the Bureau is aiming to bring about in every field. For example, through such international cooperation the electrical units and standards of England, France, Germany, and the United States are now in close agreement. Largely through the Bureau's efforts, the standardizing institutions of these countries cooperate with the Bureau in still further efforts to enhance their accuracy. In cooperation with the Federal departments, the Bureau has, during the year, secured the adoption for the entire Government of standard specifications for Portland cement and is working toward unifying specifications for other materials.

An important case of cooperation with the States is the annual conference of State officials of weights and measures at the Bureau of Standards. Through this means and without special legislation harmonious relations have been brought about with the States. Model laws and regulations have been drafted and inspection services established. The outlook is full of promise for the success of the nation-wide movement for honest weights and measures in daily trade.

In cooperation with the technical electrical interests, the Bureau has prepared reliable copper-wire tables which have been adopted as standard by that industry, which has also accepted the Bureau's definition of the horsepower in terms of scientific units.



These are several of many cases of cooperation which have been effective in their results. Much of the success of the Bureau's work has been due to the most hearty cooperation of manufacturers, consumers, and technical experts—especially where the results would enure to the benefit of all. In this way the Bureau avails itself of existing knowledge in each field and of the aid of specialists in daily touch with each subject, and the results of the Bureau's work find through these channels the most ready acceptance and application.

Standardization of industrial processes and products and the application of precise methods in science and technology have made it imperative that the Bureau keep in close touch with the advancing needs for such work and, as far as practicable, be prepared to meet such demands. The quality of materials depends upon their physical and chemical properties, each of which may be measured and standardized exactly as their dimensions are standardized. While this fact is already becoming a most fruitful factor in industry, its full application must quicken industrial progress to an extent which can hardly be overestimated. Upon this view that quality may be measured rests the importance of the movement for unified specifications for materials. Here the Bureau brings together the experience of manufacturer and user, and the best judgment of technical specialists concerning each factor which affects the quality. After a searching inquiry by correspondence, conference, and experiment, a specification is developed in which tests and attainable limits are set for the measure of each property of the material, with a view to the establishment of a standard of quality best adapted for the use intended. Such standard specifications result in more perfect understanding between the maker, the user, and the testing laboratory. Upon the determination of the properties of materials rests the adaptation of them to the uses of mankind. The "standard specification" based upon the accurately measured properties of material which constitute its "quality" and the "standard test" which determines those properties are indispensable in the efficient and economical use of materials.

With the modern demand for constancy and high precision in the standards and the elaborate means for their care, the custody and maintenance of the standards becomes a highly technical laboratory operation. The standard temperature scale and the electrical standards are examples. The testing of standards assumes a special importance from the fact that many of the tests fix the standard for important branches of industry. Likewise, the Bureau's calibration of the State standards for 10 States during the year sets the standard of trade weights and measures for those States. A similar case is the testing of gas standards for cities. The comparison of scientific

and industrial standards sets the standard measures for commerce and technology. In some cases the Bureau's testing is on an extensive scale, as, for example, the testing during the year of 18,000 thermometers, 9,000 capacity measures, 3,000 standard weights, and the inspection and testing involved in the purchase of more than 1,000,000 electric lamps, and 2,000,000 barrels of cement, the check testing of imported sugars, the analysis and testing of Government supplies, and of the structural materials used on Federal buildings. These are examples of the character of the work, of which a fuller account is given later in this report, the limits of which would be exceeded if the work of the year were reported with the fullness needed for its proper presentation. The results of much of the work will be found in the 41 publications of the Bureau issued during the year. The following report briefly summarizes the work by divisions.

### ELECTRICITY.

In the Electrical Division researches have been carried on to maintain the electrical standards, to fix them more accurately, and also to improve methods of electrical measurement and of testing. During the past year much testing was done for the Government and the public to determine whether instruments and materials conform to specifications, and what types of instruments are best suited to given purposes, to ascertain the merits of new designs, and to obtain accurate calibrations of instruments for use in important tests or in the measurement of large quantities of electric power.

Work has been continued on the mercury ohms and standard cells in order to make these concrete standards of electric resistance and electromotive force still more trustworthy. The investigation of the silver voltameter as a standard instrument for the precise measurement of electric current has been completed and will shortly be published. The investigation of the absolute measurement of electric current by a current balance has been completed and published. These fundamental researches in electrical science have been conducted with a thoroughness which marks an important advance in electrical measurements.

Investigations have been made upon the properties of electric condensers and upon the dielectric constant, absorption, and resistivity of a number of crystals, resulting, among other things, in the discovery of a substance, fluorite, which shows no absorption. For several years the effect of light upon insulators has been under investigation, and during the past year the work has been extended to include the effect of humidity. The large amount of valuable information upon this subject thus obtained will soon be published.

## PRECISION RESISTANCE MEASUREMENTS.

The precision resistance measurements have included the investigation of the methods and apparatus used in electric resistance measurements; the design, investigation, and construction of resistance standards; the determination of the electrical properties of conductors; and the testing of resistance standards, bridges, precision rheostats, potentiometers, etc.

Each year a number of the 1-ohm resistance standards of the sealed type are sent abroad for measurement in the national standards laboratories of England, France, and Germany, as recommended by a subcommittee of the International Committee on Electrical Units and Standards. These measurements show that the units of resistance now in use in these national laboratories agree in value to within 2 or 3 parts in 100,000—a degree of accuracy 10 times greater than that obtainable prior to the development at the Bureau of the sealed type.

The investigation of the resistance material *therlo*, to which reference was made in the report of last year, has been continued. In addition to continuing the record of changes in the resistance of the older standards, additional standards have been constructed. So far the results of the investigation seem to show that, as a material for use in the construction of precision resistance standards, *therlo* is somewhat better than *manganin*.

The new apparatus designed by the Bureau for testing potentiometers has been carefully tested, found well adapted for the purpose, and is now in regular use. The theory of the corrections to potentiometers has been worked out and different methods for determining the corrections studied.

During the year the constants of a number of moving-coil galvanometers were determined for the purpose of finding the relative suitability of the different instruments to the work in which they are used and to see to what extent the behavior of such galvanometers is in accordance with the theory. The measurements made show that, for well constructed instruments, all the constants can be determined with fair accuracy from the data given by five independent measurements, and that their behavior is in good agreement with the theory.

## ELECTRICAL MEASURING INSTRUMENTS.

The number of electrical measuring instruments tested during the year was greater than in any preceding year, tests of current transformers and break-down tests of insulating materials being very much in excess of previous years. Several exhaustive tests of instruments were made for the makers in order to show where improve-



ments were necessary or desirable. Exhaustive comparative tests of American direct-current watt-hour meters were begun during the year, and considerable progress was made. A new and important method of testing current and potential transformers was developed. New apparatus has been designed and constructed to measure time in the testing of watt-hour meters. This replaces the chronograph and stop watch, as it is quicker and more convenient than the former and more accurate than the latter.

#### MAGNETISM.

Magnetic properties of 58 samples of steel were determined during the year—20 involved total core losses, 21 normal induction and hysteresis determinations, and 17 special tests. These special tests indicate the changing requirements of the users of steels for electrical apparatus. While unusual now, they will undoubtedly have to be met more frequently in the future. Considerable time has, therefore, been spent in devising methods and apparatus for making such tests. Methods and apparatus have been modified so that specimens which are much larger or smaller than the standard sizes can now be tested. Upon such measurements depend largely the improved efficiency of electrical apparatus.

Measurements of permeability at very low inductions and very high frequencies, such as are common in telephony, have been made. Methods for such work need still further development and have been investigated to some extent during the year.

For the regular testing for total losses in transformer and armature steels, the tendency is toward the use of higher inductions than heretofore. Additional difficulties are thus introduced owing to a number of conditions such as the variation of the form factor of the alternator with the higher magnetizing currents needed. Effort is being made to meet these new conditions satisfactorily.

The Bureau has loaned a number of standard magnetic test bars to various educational institutions for the purpose of checking up their permeameters. In this way it is planned to secure greater uniformity in magnetic measurements.

The cooperation between the Bureau and the committee on the magnetic testing of iron and steel of the American Society for Testing Materials still continues. This cooperation in the consideration of specifications and in the carrying on of experimental work, prevents needless duplication of work. The standards committee of the American Institute of Electrical Engineers has also agreed to cooperate in this work.

The investigation on the correlation of the magnetic and mechanical properties of commercial steels with a view to discovering some simple magnetic test which may replace some of the mechanical

tests and thus avoid the destruction of the material under examination is still in progress. A large amount of data has been collected, and in every case investigated there have been magnetic differences between specimens which had mechanical differences. Without generalizing from the results already obtained, it may be stated that the outlook is very promising. For example, in a certain grade of steel such as is used in springs and tools, the magnetic tests showed whether or not it had received the proper heat treatment to give it the desirable mechanical properties.

If the material is not satisfactory, the same magnetic test shows whether the defect is in the nature of too great brittleness or too little mechanical strength. Another test on this same material will show whether it has been subjected to local strains beyond the elastic limit. In another case a steel rail which had broken in service and in which the microscope showed the presence of transverse fissures, had a decidedly lower permeability than a similar rail of the same composition which had never been in service and which showed no such transverse fissures. Defects in certain low carbon steel bars have been produced in various ways, e. g., by bending, nicking, stretching, drilling holes, etc., and in every case the good and the defective material have shown characteristic differences.

This work has been carried on with only a limited number of small specimens and by laboratory methods. As this field is almost entirely new, it will be necessary to carry on these preliminary investigations with hundreds of samples, including all the materials that are used in practice. In case the complete investigation fulfills the promise of the part already done, no reason is apparent why the same or similar methods may not be applied to the commercial sizes, e. g., full-length steel rails.

#### INVESTIGATIONS IN ELECTROLYSIS.

The investigations in the field and in the laboratory of the serious effects of electric currents upon underground structures, piping, etc., have been continued throughout the year. Results already obtained relating to the effects of electric currents on concrete have been compiled, and will soon be ready for publication. This report treats of (1) the nature and causes of the phenomena which arise from the passage of electric currents through both reenforced and nonreenforced concrete; (2) the condition under which damage to concrete structures by stray currents may occur in practice, and the extent to which trouble may be expected under practical conditions; and (3) precautions that may be taken for minimizing damage from this source in both new and old structures.

The field work relating to the subject of electrolysis of underground structures generally has been continued along the lines previously

followed. In this connection a careful study of electrolysis conditions in a number of cities is being made, in some of which the problem of electrolysis is a serious one, while in others comparatively little trouble has been experienced. A detailed study is being made of all the factors entering into the electrolysis situation in each of these places, and a careful study of all possible methods of mitigation is being carried on with the view of pointing out certain principles of general application that may be of material assistance to electric railway companies and others in securing the maximum of protection at a minimum cost.

#### PHOTOMETRY.

The two sections of this work are (1) flame standards, the calibration of photometric instruments, the testing of illuminants, and problems in illuminating engineering; and (2) the preparation and calibrating of incandescent electric standards (carbon and tungsten) and of color screens, maintenance of the primary photometric units, and the inspection and life testing of lamps for the Government. The direct relation of light measurement to human well-being makes the work in photometry of special interest and importance.

The work upon flame standards consisted largely in the calibration of pentane lamps to be used as standards in testing the gas supplied in various cities. The previous investigations of the Bureau have shown the necessity of such calibration, and the publication of this fact through the proceedings of the American Gas Institute, as well as through the Bureau's circulars and correspondence with inspectors of gas and other officials, has led to a great increase in the number of such standard lamps sent to the Bureau for test. The number certified during the past year exceeds the total of all previous years combined. Each lamp tested usually serves as the standard by which the illuminating power of the gas supply of a city is judged. The importance of this work is evident, since by such standardization the quality of gaslight is maintained.

The experience of the Bureau has made it a recognized authority on the construction and operation of pentane standard lamps. The effects of varied construction and operation of pentane lamps have been carefully studied. Many additional details and related questions still need investigation, e. g., to determine the effects (1) of variations in construction (in order to specify more exactly the dimensions of those parts which may affect its value), (2) of surrounding screens, (3) of variation in the proportions of air and pentane supplied to the burner. It would also be desirable to further verify the results already obtained in regard to the effects of atmos-



pheric conditions on the lamps and, at the same time, to extend the investigation by obtaining greater variations in those conditions, and by making comparative measurements on other flames, especially on the kinds of burners which are used in the testing of gas.

A great variety of problems in illuminating engineering has arisen during the year, several of which occupied considerable time and included tests of lighting installations as well as the illuminants themselves.

For commercial companies tests have been made of the efficiency, light distribution, and life of luminous arcs, and of the intensity and distribution of light from a number of inverted gas lamps. The Bureau has been called on for advice as to the improvement of the lighting of the Civil Service building and the economical lighting of the post office building at Baltimore. The latter was taken up by the President's Commission on Economy and Efficiency as a typical case of the lighting of public buildings.

#### WEIGHTS AND MEASURES.

During the year the field work of the investigation on the condition of commercial weights and measures throughout the country was practically concluded with inspections in Oklahoma, Louisiana, Alabama, Kentucky, Indiana, Colorado, New Jersey, and New York. The interest in the preliminary reports of the investigation continued, and a number of these were issued in typewritten form where there was immediate need of them, as in States where legislation was introduced, etc. The hearty cooperation of the State and local officers greatly enhanced the value of the results obtained, and their influence upon local conditions was in many cases prompt and effective. The reports on the cities inspected throughout the country are now practically completed and will soon be ready for the printer. When issued it is expected that a majority of the States which have not yet passed satisfactory legislation will be convinced of the necessity of so doing by the conditions revealed in these reports, and it is probable that many will take action at the following sessions of their legislatures. In this investigation startling irregularities were found in trade measures, as indicated by the brief summary of the apparatus tested during the year.

Tested.	Number of tests.			Percentage.	
	Correct.	Incorrect.	Total.	Correct.	Incorrect.
Scales.....	639	511	1,150	55.57	44.43
Weights.....	994	184	1,182	84.09	15.91
Dry measures.....	357	357	694	51.44	48.56
Liquid measures.....	242	95	337	71.81	28.19

Cogent reasons for the urgency of this subject are apparent when it is remembered that the neglect of inspection gives the dishonest dealer a distinct advantage over the honest dealer and the consumer is helpless, since the standards are in the possession of the Government. This investigation is fundamental and its effect will be far-reaching upon the weights and measures of daily trade, benefiting alike the consumer and the honest merchant.

The Bureau has assisted in the framing of local legislation, and technical assistance was also rendered, both by correspondence and personal work, by members of the Bureau staff to the States which have recently passed such legislation in establishing inspection departments.

Revision of the State and National laws on weights and measures was completed during the year, and included all of the recently enacted laws on the subject. The compilation practically represents the status of weights and measures in the United States at the present date, and should be of great value to both National and State governments in the consideration of future legislation.

The Seventh Annual Conference on the Weights and Measures of the United States, held at the Bureau on February 15 and 16, 1912, proved, both in numbers and in results accomplished, to be by far the most successful held since the inauguration of the meetings in 1905. In all, 98 persons attended, 25 States were represented, while 51 city and county weights and measures officials took part in the proceedings.

An unprecedented number of old sets of State standards were submitted for test, as well as a considerable amount of new equipment. This was largely on account of the interest manifested in the question of correct weights and measures and the interest of the States in revising their laws on the subject. While this testing of standards taxed the facilities of the Bureau to the utmost, the work was completed promptly. The standards tested were those of Connecticut, Indiana, Arizona, Minnesota, Montana, Nevada, New Jersey, Pennsylvania, Vermont, and Wisconsin, besides those of a number of municipalities.

Early in the year a thorough investigation of the fine-mesh sieves used in testing cement were made for the purpose of preparing revised specifications for Portland cement, which were put into effect by Executive order on April 12, 1912. The old specifications were found impractical and their application in actual testing resulted in the rejection of practically all sieves submitted. New sieve specifications were prepared in cooperation with the manufacturers and users, utilizing the new data gathered by the Bureau during the past four years, and they have already had a beneficial effect upon the manufacture of cement sieves.



The thermal expansion work has made substantial progress, and the Bureau is now prepared to determine the expansivity of brass from room temperature up to about 700° C.

A systematic investigation of the expansivity of materials should be begun. In the case of many substances no data appear to have been published, and in almost all instances a revision of existing data is desirable. Pure metals, analyzed alloys, and various industrial materials should be examined over as wide a temperature range as possible. The investigation should inquire into thermal hysteresis, the effects of such heat treatment as hardening and annealing, the behavior in the neighborhood of critical regions, changes in dimensions with humidity, the effects of such mechanical treatment as rolling, hammering, drawing into wires, prolonged vibrations, etc.

The third edition of Circular No. 2 on "Metal Tapes" was completely revised and enlarged to cover all Bureau tests involving measurements of length and area, including thermal expansion. In addition to the usual specifications and fee schedules, information was inserted concerning units and standards, conditions influencing the dimensions of bodies, etc.

#### MASS.

The material for a new circular on the testing of masses was prepared during the year. This comprises instructions as to the use, care, adjustment, and test of standard weights, and information and tables for use in precision work when the observed weighings were reduced either to vacuo or to some standard pressure. Tolerances for the weights submitted to the Bureau were established, as well as for commercial or trade weights for which there was urgent demand. Advance sheets of the circular were furnished for criticism to the various manufacturers concerned and valuable suggestions were received.

#### VOLUME.

A marked improvement in American-made volumetric glassware and hydrometers submitted for test during the past year is noted, the apparatus now submitted being equal, and in some respects superior, to the best grades of similar apparatus of European manufacture. This is in sharp contrast with the condition which prevailed at the time the Bureau was established, and is one of the best examples of the value of rigid specifications coupled with facilities for ascertaining whether the apparatus purchased on specifications conforms thereto. Practically all volumetric apparatus and hydrometers used in the Government laboratories are now ordered on Bureau specifications, and university and private laboratories are using them with increasing frequency.

## BAROMETRY.

Aneroid barometers are instruments of great importance to surveyors, explorers, aviators, and in scientific investigations. The Bureau has undertaken the thorough study of these instruments, which are used to measure the atmospheric pressure and from this to ascertain the altitude above or below sea level. The investigation, which included the intercomparison of a large collection of aneroid barometers representing twelve different makers, was completed during the year. The results show to what extent the errors of an aneroid are physically inherent and to what extent they may be avoided by suitable tests. In the investigation four kinds of tests were made, namely, mechanical, temperature, atmospheric, and air-pump tests.

The mechanical tests consisted (1) in determining for each aneroid the probable error of a single pointer reading as affected by parallax, tapping, etc., and (2) in calibrating the pressure and altitude scales of typical aneroids.

The temperature tests consisted chiefly in taking aneroids out doors on a very cold winter night and later heating in a receiver surrounded by hot water, with the conclusion that in good instruments thermal errors are negligible compared with other errors, and therefore need not be seriously considered until more is done to eliminate mechanical and elastic errors.

In the free atmosphere tests, 25,000 observations were taken in order to keep track of the history of each aneroid in the interim between successive air-pump tests, to ascertain to what extent it is fair to pass judgment on an aneroid from observations on the fluctuations of its correction from day to day, and to detect secular changes.

The air-pump tests were, however, the most important, and also the most laborious, as it was necessary to hold the aneroids for 24 hours at the lowest pressure in order to observe the creeping effect due to imperfect elasticity. This determination of the creep appears to be the crucial point in ascertaining the quality of an aneroid.

As a sequel to the foregoing investigation the development of standard specifications for the purchase of aneroids has been undertaken at the joint request of other branches of the Government service and of manufacturers. The final results of the Bureau's work in this field can not fail to be of great value in improving the design, manufacture, and use of these important instruments.

Special apparatus was constructed to test mercurial barometers, and especially to study several sources of error peculiar to them. To obtain the necessary range of pressure for testing high-altitude mercurial barometers, the receiver was constructed for operating the verniers and cistern screws through air-tight containers. Finally a routine method was put into practice for carrying out the necessary

manipulation, observation, recording, and computing so as to secure the greatest accuracy in the least time.

#### NEW WORK IN WEIGHTS AND MEASURES.

An investigation of variations in spring scales was commenced to determine the possible errors of certain types, especially when subjected to temperature changes, with the end in view of establishing tolerances for this type of scale. The manufacturers of spring scales showed much interest in this investigation and several submitted compensating devices designed to correct defects noted by the Bureau. This investigation should be extended to springs in general, and should include a systematic study of their elasticity, temperature coefficient, durability, and other properties, as affected by the composition of the steel and the heat treatment of the material of which they are made. Spring scales, on account of their convenience, are more largely used in this country than in any other country in the world, and any improvement in their action would be of general concern.

It is proposed to undertake the investigation and testing of railroad, elevator, and other scales used in weighing commodities for interstate shipment, and for this purpose to purchase a standard test car equipment and a standard scales of sufficient capacity. This will necessitate a special appropriation. A number of the railroads have already efficient inspection departments, and others are establishing them, but there are a number of roads that have practically no supervision of their track scales, which are defective in design and incorrect in their indications.

Since approximately \$2,200,000,000 are derived from freight, practically all of which is weighed upon some form of railroad scales, it is of the greatest importance that the scales be correct. At the present time controversies continually arise between the railroads and shippers, owing to lack of confidence as to the correctness of weighings and it is believed these controversies will in a large measure be obviated if the correctness of the scales is assured.

Certain industries, such as the grain industry, maintain their own weighmasters and scales in the more important grain markets, but the average shipper is without the means to check his weights and is compelled to pay charges determined by weighing on scales over which neither he nor the Government has at present any supervision. Most of the commodities are shipped from one State to another, and even if the States should establish inspection services to cover railroad scales a number of questions would arise that could only be settled by the Federal Government. The equipment proposed would enable the Bureau to cooperate with the State authorities, and also to standardize their apparatus for them.



**THERMOMETRY, PYROMETRY, AND HEAT MEASUREMENTS.**

The work of testing in all the sections of this division has increased very greatly in the last two years. It has been possible to meet these demands only at the expense of progress on several important investigations that are fundamental to the work of this division.

**THERMOMETRY.**

The thermometers tested in this division during the year number 17,866, made up as follows: 81 Beckmann and calorimetric thermometers graduated to  $0.01^{\circ}$  or  $0.02^{\circ}$  and used in work of the highest precision, 254 ordinary calorimetric thermometers used in determining the heating values of fuels, 9 primary standard Baudin thermometers used to define the standard scale of temperatures, 2 liquid-in-glass thermometers for measuring very low temperatures, 1,060 ordinary mercurial thermometers, and 16,460 clinical thermometers used by the medical profession. In addition there were tested in this section 7 electrical resistance thermometers, 1 thermocouple, and 1 compound differential thermocouple.

Work has been continued whenever opportunity would permit on the standardization of a number of primary standard mercurial thermometers in the range of  $100^{\circ}$  to  $500^{\circ}$  C.

A theoretical and experimental investigation of the effects of thermometric lag on temperature measurements was completed during the year and is now in press. A paper on the corrections for the emergent stem of mercurial thermometers was published during the year.

Through the courtesy of Drs. Day and Sosman an opportunity was afforded to compare several platinum resistance thermometers with their nitrogen gas thermometer up to  $630^{\circ}$  C. It is hoped that this and similar work will, in the near future, lead to international agreement as to the standard scale of temperature to be used by the several national laboratories.

**CALORIMETRY.**

An important work of the Bureau is the determination of standard heats of combustion and especially the standardization of the instruments and materials used in such work. During the year this division furnished 168 standard combustion samples of sugar, naphthalene, and benzoic acid, used by chemists and engineers to standardize the calorimeters and to check the accuracy of the methods used in determinations of the heating value of fuels.

Special tests made in this section included the test of a gas calorimeter for a public-service commission, the determination of the specific

heats of two special distillates, the determination of the heats of combustion of a special engine oil, and of an oil gas by-product for manufacturing concerns.

Considerable work has been done during the year on the investigation of various forms of calorimeters used in the industrial testing of the heating values of gases. In view of the increasing importance of the heating value in legal requirements for the sale of gas, this investigation promises results of immediate practical importance.

Some work was also done on the determination of the specific heat of copper in the temperature range within which this constant should be known with the highest accuracy for calorimetric purposes.

#### PYROMETRY.

The tests carried out in this section include 6 platinum resistance thermometers, 41 platinum alloy, and 21 base-metal thermocouples, 26 pyrometer galvanometers, 8 optical and radiation pyrometers, 53 determinations of the melting points of metals, alloys, slags, etc., an increase of about 60 per cent over that of the preceding year.

Considerable work was done on the radiation from surfaces of steel at high temperatures with a view to furnishing data to users of radiation pyrometers, which would enable them to reduce observations with these instruments to true temperatures. This investigation is being extended to the radiation from nickel and other metals.

An investigation was completed during the year on the melting points of 54 samples of fire clay, bauxite, silica, magnesia, and chromite bricks. Work is in progress on the melting points of pure refractory oxides such as magnesia, lime, etc. It has been found that some of these materials have much higher melting points than has been supposed.

A paper on the present status of the temperature scale was communicated to the recent International Congress in Applied Chemistry.

Circular No. 35 was compiled and issued during the year, giving a summary of our present knowledge of the melting points of the elements.

A committee of the International Photometric Commission has expressed the desirability of having experiments carried out on a primary standard of light along the lines suggested by two members of this division in a paper published some years ago in the technical press.

A number of industrial plants have very complete temperature measuring installations. It is most desirable that convenient means be afforded these plants which would enable them to check the accuracy of the pyrometers from time to time, in much the same way



that the Bureau has enabled users of calorimeters to check the results of their tests by furnishing standard combustion samples. This can be done by furnishing standard melting-point samples, consisting of a series of metals and salts of accurately known melting points. The necessary assistance should be provided as soon as possible to enable the Bureau to furnish such standard samples.

The measurement and control of high temperatures is receiving rapidly increasing attention in many industrial lines, and an important part of the work of this division consists in furnishing information bearing on these questions. Our laboratories are visited almost daily by engineers and technical men interested in temperature problems.

#### METALLURGY AND METALLOGRAPHY.

The tests carried out in this section include the determination of the heating and cooling curves of 6 samples of steel and 11 metallographic tests. A paper on the work on metallurgy was recently published in the technical press by a member of this division. Work was continued throughout the year on the factors influencing the recalescent points in pure iron and in iron alloys, and on the methods of determining heating and cooling curves.

#### MISCELLANEOUS.

Other tests carried out in this division were as follows: 18 special tests, such as the freezing and absorption tests of bricks, heat tests of miscellaneous materials, etc.; flash-point and viscosity tests of 85 samples of lubricating oils.

Two papers were published in the Bulletin during the year by a member of this division on a method of computing the constant of Planck's equation for the radiation of a black body and on the steam turbine expansion line on the Mollier diagram.

#### OPTICS.

##### SPECTROSCOPY AND APPLIED OPTICS.

In connection with the investigation of conducting gases as photometric standards, a set of 40 helium tubes prepared as primary candlepower standards of light in accordance with the results of previous work were measured up. The results showed that the proposed standard has the requisite reproducibility. A comparative test of sources suitable for photographic spectrophotometry led to the adoption of the condensed tungsten spark in air, operated on a 10,000-volt transformer as the best. Tubes of improved design filled with pure gases have been supplied various optical laboratories

as light sources. The demand for these tubes is rapidly increasing. Various spectroscopic tests of chemicals have been made and an investigation of the spectra of acetylene and methane is under way.

A large number of optical instruments and accessories have been tested during the year along the lines laid down in Circular No. 27, which appeared early in the year. These tests include the determination of the residual aberrations, focal length, and aperture of photographic objectives of all kinds, small telescope objectives, microscope objectives and oculars; and the field covered magnification, light loss and definition of telescopes, reading microscopes and projection apparatus. The radii of curvature of numerous lens surfaces and test pieces have been determined. Applications for determinations of shutter speed have been received.

Investigations carried on include a comparative determination of the properties of a series of wide-angle objectives and considerable work on high speed and process lenses. Methods of determining aberrations have been devised and developed until the list is practically complete. Tests of photographic test charts have been made and new ones devised suitable for rough, rapid tests. A study of the limits of tolerance in the errors of various classes of objectives is under way. A precise rapid method of determining shutter speed has been devised.

Many determinations of refractive indices have been made during the year. These include very precise (6-place) determination of standard test liquids and glasses. certification of the standard plates used by chemists to check the scales of direct reading refractometers, the determination of index and dispersions of optical glasses, precise determinations of egg albumen (age test) for the Department of Agriculture, and numerous rough determinations (4-place) of various oils, solutions, and crystals.

A large spectrometer of the highest obtainable precision and a set of prisms for reference standards have been added to the equipment. Several direct reading refractometers have been tested and certified. An investigation of commercial refractometers with a view to improvement in sensibility and precision is under way.

The precise measurement of color has received a great deal of attention during the past year. An absolute color analyzer, giving analyses directly in terms of wave lengths of the dominant hue and the per cent white impurity, was devised and is now in use.

A large number of card and glass reference standards of color have been standardized and certified. Standardization of the reference standards used in the purchase and sale of cotton oil is under way. Work is planned on the methods of color analysis and standardization of the colors of textiles, papers, tobaccos, butter, dyes, liquors, etc.

An extended series of comparisons of direct midday sunlight with the light of the acetylene flame have shown that the former is a satisfactory constant working standard as well as an ideal white light. Using such sunlight as standard white, the variations in the colors of various sources with temperature or total radiation are being investigated.

A great many absorbing screens of various kinds have been tested during the year. A comparative test of photographic ray filters for the Government indicated those which sacrifice least of the active desirable light and yet possess the desirable absorption of blue and red. The efficiency of the photographic safe lights for use with different kinds of plates has been determined. Numerous absorption glasses for protecting the eye from injurious ultra violet radiation and absorbing a minimum of visible light have been investigated with the result that American-made glasses are now available which are more efficient than the best imported ones.

The reflecting and diffusing powers of various surfaces and transmission screens, now receiving so much attention by illuminating engineers, have been investigated. A new, rapid, and precise instrument for determining reflecting power has been perfected, used in our testing, and made available to the public. Another instrument has been devised and used in determining the distribution of the reflected and transmitted light. A number of determinations of reflecting power have been made on materials sent in for test.

Data on the injurious effects of ultra violet light in various illuminants have been sought by the public and have been supplied as far as available. A preliminary investigation of this subject has been carried out with the cooperation of the Treasury Department, and a more detailed investigation planned.

The fundamental principles and methods of colorimetry depend upon the sensibility of the human eye to differences in wave lengths and purity, and similarly those of photometry to differences in brightness. These sensibilities are being investigated by new and improved methods and valuable data are being obtained.

#### POLARIMETRY.

Work in connection with the standardization of sugar analysis by means of the polariscope test has been carried on by the section of polarimetry for the Customs Service and the public. During the past year the control of sugar analysis at the various ports of entry by check analyses of samples transmitted daily has been continued. The efficiency of the method continues to show itself by the constantly increasing accuracy of the analytical results obtained at the ports of entry. The new type of adjustable saccharimeter as devel-



oped at the Bureau has been introduced into the Customs Service and a still higher accuracy is anticipated. Many quartz plates used in the daily control of the saccharimeter have been tested and certified for the Treasury Department and for the public.

The determination of the hundred per cent point of sugar-testing instruments is one of the fundamental problems of polarimetry. An investigation for the purpose of determining this important constant has been under way since the organization of this section and is now practically completed. The investigation of the hundred per cent point of the saccharimeter has developed the fact that an important error exists in the accepted value of this fundamental constant. To eliminate all uncertainty this investigation will be continued.

The preparation and distribution of standard sugar samples of sufficiently high purity to be used to test saccharimeters and calorimeters has been continued, and by a careful study a greater certainty of analysis has been attained.

A most fundamental problem in polarimetry as well as optics in general at the present time is the production of monochromatic light of considerable intensity. Considerable time has been devoted to this subject in the polarimetric laboratory, and within the year an instrument has been perfected which appears to solve this important problem.

During the year a temporary constant temperature room has been installed, permitting the extension of the work into a number of new fields. Several new researches have been started, and the work of preparing pure sugar from a wide range of sources has been carried on.

Owing to the amount of vacuum work incident to the work of this section, a new vacuum pump has been designed and perfected, which not only produces the highest vacua with great rapidity, but does it for the first time without the aid of an auxiliary air pump. These features have an important bearing on the constantly increasing use of high vacua in the arts and sciences.

#### RADIOMETRY.

Work has progressed on the radiation constants of the so-called "black body" (a uniformly heated inclosure). This concerns standard radiation of energy and the divergence of various sources from such standard radiation, a problem which underlies the theory of pyrometry, photometry, and spectroscopy.

The "blackness" of the radiator was specially studied by nine series of spectral energy curves obtained with two porcelain tube furnaces. Energy curves were obtained from the white porcelain tubes; then similar curves were obtained at the same temperatures when the inner walls of these tubes were painted with chromium

oxide, with cobalt oxide, or combinations of these two oxides. In all, 91 energy curves were obtained using different prisms, different adjustments of the same prism, different water cooled shutters, and different thermocouples.

A new paper entitled "Instruments and Methods of Radiometry" is now ready for publication. The paper contains information for the specialist as well as for the beginner, and was prepared in response to numerous requests by both types of inquirers for information upon this subject. No authoritative or complete treatise on radiometry is available.

Until recently psychologists have been using light stimuli without knowing their mechanical equivalent. All such work must, therefore, be repeated; and now they are confronted with such difficulties as (1) lack of training in radiometry, (2) lack of simple instruments which are sufficiently sensitive to measure light stimuli, and (3) lack of standard of radiation. Surface thermopiles of bismuth and silver were constructed and tested (likewise the light filters which absorb all the infra-red) to meet the needs of this class of investigators.

A new paper entitled "Selective Emission of Various Substances" has been prepared for publication concerning (1) the radiation constants of platinum, (2) the emission spectrum of neon and helium, (3) the emissivity of different parts of the acetylene flame, (4) the variation of emissivity with thickness of the radiating layer, oxides, (5) standard spectral energy curves, and (6) light filters which absorb all the infra-red. The investigation of the radiation constants of platinum proves a far more extensive research than might be suspected. The results obtained confirm the previous researches in this series, showing that the metals have no radiation constants.

The maximum emission of neon radiation lies in the visible (red) spectrum, which does not obtain in other gases.

Further data on the Nernst glower and tungsten were prepared for publication in "Selective Emission of Various Substances IV; Standard Spectral Energy Curves." A new quartz mercury vapor lamp has just been prepared for producing intense spectral lines, with which it is intended to find the absorption in the short focus spectrometer to be used in this investigation.

In an interesting radiometric investigation of the manner of production and the quality of the light emitted by fireflies two noteworthy facts were ascertained—(1) the maximum of the light emission is different in different species, not an optical illusion as was supposed, and (2) the temperature of the luminous organs is higher than that of the adjacent nonluminous segments. The study of the physics of light production in such insects may yield results of great practical utility.



The recent purchase of one of Abbot's standard silver-disk pyrheliometers will enable the Bureau to compare its measurements of radiation in absolute measure with the Abbot primary standard. A primary standard similar to Abbot's in type but different in design will be constructed and a small dividing engine for cutting surface bolometers was recently constructed in the instrument shop. Several surface bolometers were acquired, making it possible to intercompare this type of the Bureau's instruments with those of other makers. The utility of the Callendar radiobalance as an absolute standard was investigated and found wanting.

An investigation of much technical importance is the determination of the diffuse reflecting power of various substances for different spectral regions, e. g.,  $0.6\mu$ ,  $1.0\mu$ ,  $4.4\mu$ ,  $9.0\mu$ ,  $3.0\mu$ , etc. The radiometer consists of a surface thermopile of 22 elements in a space of 11 millimeters, the total width being 5 millimeters. Numerous substances have been examined, including various kinds of lampblack, platinum black, green leaves, building material, cloth pigments, etc. As the Bureau is a final court of appeal when physical constants are in dispute, it can not consistently or authoritatively use data for the accuracy of which it can not vouch. An excellent illustration of this point is the question of the diffuse reflecting power of lampblack, and of pigments in general, which investigation is now nearing completion in this Bureau. New and apparently accurate data were published elsewhere, the results of which gave an "apparent" reflecting power from two to three times the "true" value.

#### INTERFEROMETRY.

The determination of 10 wave lengths of neon has been published. The values obtained are thought to be accurate to 1 part in 5,000,000, or better, and will be useful spectroscopic standards.

Attention has been given to elaborating definite methods for the use of the neon wave lengths in interferometry. Extensive tables have been prepared to facilitate the determination of the order of interference. It is expected that the neon lamp will be of great value in future work in interferometry.

Experiments have been made in the preparation of iridium mirrors by kathode disintegration, and some very good mirrors prepared for laboratory use. A modification of the original kathode method has been devised and used with some success in the preparation of very thin mirrors.

The determination of expansion coefficients by interferential methods has been put upon a working basis. Three coefficients have been determined for the Coast and Geodetic Survey. Attention has and is still being given to improving the methods for determination of expansion coefficients.

## CHEMISTRY.

The research work of the Chemical Division has resulted during the year in the preparation of papers upon the following subjects: The determination of manganese in vanadium and chrome-vanadium steels; the determination of chromium and its separation from vanadium in steels; a rapid method for the determination of vanadium in steels, ores, etc., based on its quantitative inclusion by the phosphomolybdate precipitate; a new method for the determination of vanadium—and explanation; the reduction of vanadic acid in concentrated sulphuric acid solution by hydrogen dioxide and by persulphates; the hydrolysis of sodium oxalate and its influence upon the test for neutrality; the standardization of potassium permanganate solution by sodium oxalate; the determination of manganese as sulphate and by the sodium bismuthate method; the use of benzoic acid as an acidimetric standard; an improved extraction apparatus; a new apparatus for vacuum sublimation; preliminary report on the quality of platinum laboratory utensils; errors in the determination of moisture in coal; a modified form of stability test for smokeless powder and similar materials; the evaporation test of mineral lubricating and transformer oils.

The researches now in progress include: Methods of analysis of phosphate rock, with special reference to the determination of alumina; action of lubricating oils; methods of direct determination of rubber; exact determination of physical constants of pure alcohol (a work necessitated by the wide use of alcohol as a solvent); methods of testing and analyzing illuminating gas; causes and effects of electrolysis on concrete; the investigation of waterproofing materials; the effect of atmospheric conditions of roofing terne plates; the exposure tests of 125 paints made from systematic combinations of 13 primary pigments; effects of water emersion upon paints for metal surface. The determination of the atomic weight of bromine is about completed and will be published in the fall.

During the year 1,091 samples of standard analyzed materials were distributed for check testing the accuracy of technical analyses. New standard samples of three special steels were prepared during the year. Standard samples of chrome-tungsten steel are now under analysis by a corps of chemists of acknowledged repute and skill in such analyses, and will shortly be issued in the regular series. Special difficulties were met in the preparation of the standard cast brass samples which it is expected will soon be overcome. It is gratifying to report that one of the prominent chemical manufacturers has succeeded in manufacturing on a large scale highly pure sodium oxalate, which the Bureau has established as a standard for oxidimetry in volumetric analysis.

Members of the Chemical Division have cooperated in the revision of the methods of coal analysis and the determination of water in coal and other fuels and minerals.

In the determination of the properties of materials the following classes of materials were investigated: Irons and steels, metals and alloys and other iron and steel, coated metals, cements, asphalt, felts, etc., linseed oil, oil driers, paints and paint materials, varnishes, lubricating oils, sealing wax, rubber, papers, printing inks, wool, flax packing asbestos, insulating tape—a total of about 8,613 materials analyzed and certified.

### ENGINEERING INSTRUMENTS.

The testing of engineering instruments during the year consisted chiefly in the rating of water-current meters for the Geological Survey, Reclamation Service, for a State Water Supply Commission, and for State universities. The instruments calibrated included 201 stream meters, 37 pressure gauges, 10 anemometers, 4 water meters, 2 fire extinguishers, 2 steam-engine indicators, 1 ship speedometer, and 1 tachometer. A new type of fire extinguisher was also tested and reported upon to the Treasury Department.

At the request of the Secretary of the Treasury an extended test of portable vacuum cleaning machines was undertaken for the Office of the Supervising Architect of the Treasury Department. Twenty-two machines submitted by 15 different manufacturers were tested. Methods of measuring the air were investigated and new apparatus was designed. Electrical efficiency curves were plotted, as well as curves showing the relation of vacuum maintained to volume of air moved, and an extended sweeping test was made to obtain a rating for the machines as cleaners. Suggested changes were made in the specifications of the Treasury Department for portable vacuum cleaners. A detailed report of the tests was made to the Treasury Department.

An investigation of methods of testing water-current meters in different countries resulted in the development of designs for a testing tank to be installed at the Bureau. The tank will be of the straight-away type, about 400 feet in length, and specially adapted to testing anemometers as well as water-current meters. This equipment will enable the Bureau to investigate these important instruments and greatly facilitate their testing.

### ENGINEERING, STRUCTURAL, AND MISCELLANEOUS MATERIALS.

#### METALS.

Installation of the two Emery machines has been in progress for the past fiscal year and the smaller machine of the two, having a capacity of 230,000 pounds for loads of tension and compression,



has been erected and preliminary tests made upon it. The larger Emery machine, of 2,300,000 pounds capacity, has been installed so far as the main machine parts are concerned and the Bureau is now awaiting the delivery of the weighing mechanism which will complete the installation. An accumulator system has been provided for use in the joint operation of these two machines, consisting of three independent accumulators, one of which is compound. This equipment is located in the Washington laboratory of the Bureau. At Pittsburgh a new building has been completed for housing the several machines located at the laboratory. The 10,000,000-pound Olsen testing machine has been erected and tests upon it are now being made. This machine is located in the new building and all of the testing machines have been grouped in the same room. Increased machine facilities have been provided for the fabrication of special tools and equipment and preparation of specimens for test purposes.

Both laboratories have been called upon as heretofore to make investigative tests and tests for acceptance of current supplies for different departments of the Government. The Bureau has also been called upon by engineering societies to conduct investigative tests. Arrangements are being made to conduct such tests in cooperation with several of the technical societies.

Specifically, the laboratories have been engaged on strain measurements of bridges, buildings, and also the lock gates, emergency dams, and walls of the Panama Canal. Compression tests of structural members have been arranged for in cooperation with committees of the American Society of Civil Engineers and the American Railway Engineering Association. Current work has included an inquiry into the properties of railway material and the contributory causes of railway accidents. The work on railway material has been conducted at the request of the Interstate Commerce Commission, while the work at the Isthmus has been in cooperation with that of the Isthmian Canal Commission. The Bureau has also been called upon to aid the War Department and the Navy Department in regard to the structural state of steel forgings.

In addition to the work on metal testing the Bureau is engaged on inquiries of strength of woods intended for dry-dock purposes on behalf of the Isthmian Canal Commission. This inaugurates a line of work which will embrace an inquiry into the properties of the different native North American woods and those which are found in the insular possessions of the country.

#### CEMENT.

*Cement testing.*—A total of 19,365 samples of cement were tested at the Washington, Pittsburgh, and Northampton laboratories during

the year, representing in Government purchases over 2,000,000 barrels of Portland cement. Physical tests were made on the samples to determine their specific gravity, fineness of grinding, time of setting, soundness in air, water, and steam, and tensile strength.

Practically all of the tests were made for the Government departments, each laboratory inspecting and testing the cement purchased in its particular field. Samples of the cement used in the construction of Federal buildings throughout the country and miscellaneous samples received from the Government departments and the public were tested, and the testing and supervision of sampling and shipments at the mill for the Government departments were made in connection with the testing in the Washington laboratory. The Pittsburgh laboratory supervised similar work in connection with purchases made in the vicinity of Pittsburgh. At the Pittsburgh branch the routine cement testing is done for the United States Army Engineers in connection with the erection of dams along the Ohio River. Shipments have also been made to several of the dry docks along the Atlantic coast, erected under the supervision of the Navy Department. The cement for the Isthmian Canal was tested at Northampton. The decrease in shipments to the Canal Zone caused a falling off in the work at Northampton by 20 per cent as compared with the preceding year. The work of the Washington and Pittsburgh laboratories increased about 50 per cent.

*Cement specifications.*—A conference of Government engineers of the various departments was held at the Bureau of Standards for the purpose of unifying the specifications for Portland cement used by the United States Government. A specification was developed which was unanimously adopted by this conference on February 13, 1912. Conferences were also held with committees of the national engineering societies, and substantial agreement was reached on all but a few points. On April 30, 1912, the President issued an Executive order requiring that the new specifications be used in all purchases of cement. The Government thus obtains a product of assured quality and at a saving owing to definite requirements and greater competition in bidding. The standardization of product also benefits the public consumer. It is hoped complete uniformity of specification may soon be attained for the entire industry for both the Government and the public.

*Investigations upon cement and concrete.*—Investigative work in the cement section is being carried on to obtain information in regard to the constitution of Portland cement, and how the physical properties are changed by differences in the composition and consequent differences in the constitution. For this purpose there has been erected at Pittsburgh a 2 by 20 foot rotary kiln with the necessary



grinding apparatus. There has also been established in this connection a petrographic laboratory, and, in addition to the usual chemical and physical tests of the cement manufactured, a complete petrographic analysis is made. The subject of the hydration of cement is also being taken up in this line. The kiln is also used for making burnings of raw materials submitted by the general public for a nominal fee.

The investigation of the action of sea water on cements, mortars, and concretes was continued, and an exposure station was established on Government property at Charleston, S. C., to continue the work started at Atlantic City, N. J. A technologic paper, now in press, gives the preliminary results of the laboratory and field investigations. The completed results of the investigation on the effect of alkali salts on cement are included in this publication.

A field and laboratory investigation of the permeability to water of structural materials is in progress. The results are urgently needed by the Government as well as the public in the design of structures where impermeability or protection against dampness are a necessity. The work involves both laboratory and field tests.

An investigation of the volumetric changes which take place in concrete structures owing to temperature variation in the hardening of concrete is being made to determine the necessity of expansion or contraction joints or the causes of cracking in concrete structures. Reference marks are placed on structures which can be measured from time to time and volumetric changes noted.

It is proposed that the testing of cement include an exposure of the cement to high-pressure steam. The value of such a test as a means of indicating the structural quality of cement is under investigation by the Bureau. The effects of heat, moisture, and pressure are being separately investigated.

#### PITTSBURGH BRANCH OF THE BUREAU.

The Pittsburgh branch of the Bureau of Standards is located on the grounds of the Pittsburgh storage and supply depot of the United States Army, and occupies the Army building (known as No. 10), a brick kiln house erected since the ceramic work was started at Pittsburgh, and a new building just erected by the Bureau to contain the large testing machines. Building No. 10, approximately 44 by 210 feet and 45 feet high, contains two floors, each floor being divided into offices and small laboratories. On the second floor are located the chemical laboratory, ceramic laboratories, the main lime laboratory, the library, the petrographic laboratory, and general offices. The first floor is divided into larger rooms for the heavier machines re-

quired in the work. Here the main laboratory of the ceramic section occupies the front of the building. On this floor is located the laboratory for the physical testing of cement and concrete, as well as the machine shop, the carpenter shop, and two rooms for the storage of material.

The kiln house is a one-story brick fireproof building 30 by 80 feet and 20 feet high. The larger part is occupied by kilns of the ceramic department and includes two down-draft natural-gas fired kilns—one 30 by 36 inches and one 32 by 40 inches; also a 20-inch circular kiln and furnace for testing fire brick under loads, as well as two small carbon resistance furnaces for determining the softening points of clays, bricks, and porcelains. The smaller section of the kiln house contains the 2 by 20 foot rotary kiln for cement burning, as well as the crusher, hammer, and ball mills for grinding the raw mix and cement clinker.

The new building is approximately 45 by 90 feet and 60 feet high, with an engine and boiler room and a section connecting it with building No. 10. The latter section is divided into two stories, the upper being used as offices and the lower as a storage room for the machine shop, which it adjoins. The main building houses one 100,000, two 200,000, one 600,000, and one 10,000,000 pound testing machines—all of the Olsen type—as well as several smaller machines used for various purposes. In order to handle the large specimens for the larger machines a 20-ton crane is provided, the gantry of which is sufficiently high (40 feet) to clear the top of the large testing machines. This also extends about 40 feet beyond the north side of the building, enabling the crane to pass out of the building and over a railroad siding and pick up large specimens directly from the cars.

#### CERAMICS.

With the rapidly increasing cost of wood as a building material, with the growing demand for fireproof construction, for more satisfactory sanitary conditions, for permanent roads throughout the country, for a more artistic architecture, and for the development of the American clay industries to replace the large importation, the subject of clays and clay products becomes an important one in our present civilization. The many technical problems connected with the utilization of clays, and the testing of their products, have rendered it advisable to provide facilities for work along these lines, especially since the Government is a large user of ceramic structural materials. This has been done at the Pittsburgh laboratories, where the necessary machines for the grinding, preparing, and molding of clays are available, together with ample kiln space for reaching any

desired temperature. Electric furnaces for the determination of the higher softening points of silicates, and all apparatus for the physical and chemical study of silicate mixtures, are provided. Use is also being made of the testing machines of the Pittsburgh branch for the determination of compressive and tensile strength, etc. Many tests are being made of ceramic materials for the various Government bureaus, such as the Supervising Architect of the Treasury, the Isthmian Canal Commission, the Reclamation Service, and the Geological Survey, as well as for a number of State surveys.

Among the researches now being carried on are the following: The influence of time upon the rate of vitrification, the viscosity of porcelain bodies, the behavior of clay refractories, the crushing strength of burnt clay as related to porosity, the production of high-temperature porcelain, the dehydration of clays, the development of vesicular structure in clays due to overfiring, and a study of paving bricks in connection with their wear in actual use.

#### LIME.

Although lime is one of our oldest building materials, no attempt has been made until very recently to standardize its quality. The tendency to found modern building codes upon an exact basis has shown that standard specifications for lime are needed. The demand comes especially from the various cities and from the National Lime Manufacturers' Association.

In attempting to satisfy this demand a series of tests have been devised by which limes can be compared with regard to the following properties: Chemical analysis, plasticity (or spreading quality), carrying capacity, color, waste (the proportion of lumps of hard material which must be screened out before the lime can be used), yield (the volume of standard paste obtained by slaking unit weight of lime), hardness, crushing strength, tensile strength, and shrinkage. The applicability of these tests has been determined by trying them out on a large number of representative samples of all kinds of lime and hydrated lime, and they are now available to the general public for a nominal fee.

Research work is being carried out to determine whether the above tests cover all of the important properties of lime, and whether they can be improved by being made more nearly scientifically exact without sacrificing practical applicability.

It has also been found necessary to investigate the influence of the processes upon the properties of the material. Moreover, it would be inadvisable to demand a certain quality of lime without due regard to its commercial production and application. The discovery



of new uses for lime, or the study of the adaptability of different kinds of lime to different uses, should be of benefit to the industry as a whole.

The Bureau is at present cooperating with the National Lime Manufacturers' Association and the American Society for Testing Materials to formulate standard specifications for lime.

#### PAPER AND TEXTILES.

The Bureau tested during the year 2,046 samples of paper of all grades used by the Government. In addition to the routine work of the paper-testing laboratory, considerable work has been done in the process of installing additional equipment for the production of standard paper samples. This equipment will soon be ready for use. Some preliminary work has been done toward making permanent standard slides of different paper-making fibers. Analine colors were chosen to match the color given to the fiber by the zinc-chloride-iodine-potassium-iodide stain. Sufficient investigation has been carried through to encourage hope in the successful outcome of these investigations.

The textile laboratory is now in a position to make all physical and chemical tests on raw and unspun fibers, yarns, twines, and fabrics. The Bureau has investigated the effect of moisture on the tensile strength of yarns of all kinds, also the length of test specimens for tensile strength tests. A large number of scouring tests on raw wool were made to determine the percentage of grease present, the amount of moisture contained, and the regain; samples being secured from manufacturers in different parts of the country.

The Bureau has also begun the standardization of fabrics, yarns, and twines by the foundation of standard specifications for use in the various Government departments. These specifications are drawn up from actual samples obtained from the various Government bureaus. During the year 514 different textile samples were tested and certified.

#### RUBBER AND MISCELLANEOUS MATERIALS.

During the past fiscal year, the work of the miscellaneous laboratory has comprised the testing of the physical properties of miscellaneous materials, such as mechanical rubber goods, leather, metals, packings, etc., for the various Government departments; investigations of the physical properties of rubber, and the development of special testing machines and improved methods of testing.

The large quantities of mechanical rubber goods received for test from the Isthmian Canal Commission and the General Supply Com-

mittee made it necessary to devise means for facilitating and expediting the work. A number of special testing machines have been designed and are now in operation, thus greatly increasing the capacity of the laboratory.

The materials tested during the past fiscal year include rubber hose, rubber dredging sleeves, gaskets, rubber valves, packing (rubber, asbestos, flax), rubber belting, rubber bands, leather belting, iron and steel, brass and bronze, insulated wire, rawhide belt lacing, brushes, linoleum, steel punches, fiber board, insulating tape, sash cord, brass valves, metal tape, paper fasteners, stitching wire, sheet metal, galvanized conduit, and condenser tube—in all, a total of 993 different samples.

The following investigations are now being conducted: (1) A study of the properties of elastic rubber bands and the development of an accelerated test for determining their life and efficiency; (2) a study of the properties of leather belting and methods of testing with a view to the improvement of present specifications; and (3) a study of the aging properties of various rubber compounds such as are used in the manufacture of mechanical rubber goods, and the development of an accelerated test to determine the life of such compounds.

Several manufacturers of rubber goods have rendered material assistance in these investigations by furnishing the necessary rubber compounds for test. It is hoped that in the near future it will be possible to install an experimental mixing plant at the Bureau in order that every stage of the work may be directly under our supervision.

#### THE OFFICE.

##### LIBRARY.

The number of accessioned volumes in the Bureau library is now 9,340; 284 periodicals, 189 of which are by exchange, are currently received here and at Pittsburgh. The extra copies of copyrighted books relating to the Bureau's work have been transferred from the Library of Congress to the Bureau, as in the previous year. More than 1,000 volumes have been thus transferred, covering all copyright deposits previous to the current year.

##### PUBLICATIONS.

During the past year 41 new publications were issued by the Bureau, as follows: Scientific papers, 26; technologic papers, 9; circulars, 3; miscellaneous, 3. The circulars related to "Copper Wire

Tables," "State and Municipal Regulations for the Quality, Distribution, and Testing of Illuminating Gas," and "United States Government Specifications for Portland Cement." The miscellaneous publications were: "The Sixth Annual Conference on the Weights and Measures of the United States," "State and National Laws Concerning the Weights and Measures of the United States," and a descriptive pamphlet concerning the organization and work of the Bureau of Standards.

#### PERSONNEL.

During the fiscal year 1912, the personnel consisted of 192 persons employed in statutory positions and about 80 upon special research and investigation specially authorized by Congress. The statutory positions were classified as follows:

Scientific.—1 chief physicist, 1 chief chemist, 2 associate chemists, 2 physicists, 12 associate physicists, 32 assistant physicists, 7 assistant chemists, 38 laboratory assistants, 15 aids, 12 laboratory apprentices, and 3 laboratory helpers: total, 125.

Office.—Secretary, 1 storekeeper, 1 librarian, 14 clerks, 1 packer and shipper, 5 messenger boys; total, 23.

Operation of plant.—Superintendent of mechanical plant, 4 assistant engineers, 2 electricians, 3 firemen, 3 watchmen, 1 messenger, 5 skilled laborers, 4 laborers, 3 janitors, 2 female laborers, 1 telephone operator, 1 elevator boy; total, 30.

Construction.—1 chief mechanician, 8 mechanicians, 2 skilled woodworkers, 1 draftsman, 1 glass blower; total, 13.

#### SUMMARY OF TESTS.

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. A certain amount of this work is already organized upon an accurate routine basis. Much of it, however, involves investigation of the scientific principles underlying the test, a study of existing methods, and the development of new standard tests of known accuracy. In such cases the research which must precede the actual testing is a most important function of the Bureau. For the test a reasonable fee is charged, except when made for the National or State Governments. The corresponding amounts for Government testing are of interest, however, and are added to the statement of tests which follows.



*Number and value of tests completed, fiscal year ended June 30, 1912.*

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length.....	405	\$1,008.65	207	\$356.35	612	\$1,365.00
Mass.....	2,230	1,245.35	945	566.15	3,175	1,811.50
Capacity.....	8,302	3,420.41	933	568.75	9,235	3,989.16
Temperature.....	3,513	1,563.50	11,584	3,727.44	15,097	5,290.94
Hydrometry.....	2,002	1,867.25	173	220.50	2,175	2,087.75
Miscellaneous.....	6	7.00	12	20.70	18	27.70
Optical.....	1,289	1,373.10	49	162.00	1,338	1,535.10
Electrical.....	269	794.10	336	2,041.40	605	2,835.50
Photometry <sup>1</sup> .....	4,503	11,635.50	386	1,338.50	4,889	12,974.00
Chemical <sup>2</sup> .....	9,367	58,062.30	921	1,775.89	10,288	59,838.19
Physical and mechanical tests:						
Engineering (miscellaneous).....	1,112	1,736.50	13	42.00	1,125	1,778.50
Engineering instruments.....	223	1,064.00	32	144.50	255	1,208.50
Structural materials.....	21,658	39,508.06	111	565.75	21,769	40,073.81
Paper and textiles.....	2,571	2,990.50	44	76.75	2,615	3,067.25
Total.....	57,450	126,276.22	15,746	11,606.68	73,196	137,882.90

<sup>1</sup> In addition, the Bureau inspected 1,199,974 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to \$11,724.47 additional.

<sup>2</sup> 4,317 of these tests, amounting to \$41,239, were chemical tests made on structural materials.

The receipts for tests were as follows:

Total receipts, 1912.....	\$12,690.34
Received prior to July 1, 1911, for tests completed in fiscal year 1912.....	\$353.12
Outstanding fees.....	28.00
Refunds.....	15.00
	396.12
	13,086.46
Received for tests completed, fiscal year 1911.....	378.53
Received for tests in progress at close of fiscal year 1912..	1,101.25
	1,479.78
Fees for tests completed, fiscal year 1912.....	11,606.68

#### FINANCIAL STATEMENT.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1912, 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, 1912:

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries.....	\$236,340.00	\$214,554.43	\$9,535.36	\$12,250.21
Equipment.....	52,027.50	41,455.75	10,436.33	135.42
General expenses.....	25,702.77	22,075.19	3,321.24	306.34
Grounds.....	3,000.00	2,574.52	336.19	\$9.29
Investigating effects of electric currents.....	15,000.00	13,138.43	1,843.35	18.22
Testing structural materials.....	78,533.50	68,167.90	10,326.57	39.03
Testing of structural materials of the United States.....	23,350.00	15,000.00	8,350.00	.....
Testing machines.....	30,000.00	25,635.71	4,340.14	24.15
Testing machine at Pittsburgh, Pa. (continued).....	25,000.00	22,049.52	1,793.96	1,156.52
Laboratory.....	200,000.00	69,875.04	114,427.06	15,697.90
Total.....	688,953.77	494,526.49	164,710.20	29,717.08

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1912:

Appropriation.	1910				1911			
	Total appropriation.	Disbursement.	Lia-bility.	Balance.	Total appropriation.	Disbursement.	Lia-bility.	Balance.
Salaries.....	\$165,280.00	\$160,461.01	.....	\$4,818.99	\$201,440.00	\$189,552.27	.....	\$11,887.73
Equipment.....	46,000.00	45,771.06	\$108.53	120.41	46,000.00	42,405.10	\$3,526.55	68.35
General ex-penses.....	17,500.00	17,271.91	216.95	11.14	20,042.37	19,968.62	3.87	69.88
Grounds.....	3,000.00	2,963.63	.....	36.37	3,000.00	2,785.57	.....	214.43
Investigating effects of electric currents.	.....	.....	.....	.....	15,000.00	14,859.28	31.90	108.82
Gaslight standards.....	10,000.00	9,955.10	10.00	34.90	.....	.....	.....	.....
Testing structural materials	.....	.....	.....	.....	55,109.10	54,921.81	.....	187.29
Weights and measures.....	10,000.00	7,629.90	.....	2,370.10	10,000.00	9,081.89	.....	918.11
Freight truck..	4,000.00	4,000.00	.....	.....	.....	.....	.....	.....
Total.....	255,780.00	248,052.61	335.48	7,391.91	350,591.47	333,574.54	3,562.32	13,454.61

Respectfully,

S. W. STRATTON, *Director.*

TO HON. CHARLES NAGEL,

*Secretary of Commerce and Labor.*











