

Annual Report

of the

Director of the Bureau of Standards

to the

Secretary of Commerce and Labor

for the

Fiscal Year Ended June 30, 1910



Washington
Government Printing Office
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DIRECTOR OF THE BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE AND LABOR,
BUREAU OF STANDARDS,
Washington, July 1, 1910.

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, 1910:

DIVISION I.—ELECTRICITY.

Reference was made a year ago to the international cooperative investigation on electrical standards which was to be carried on at this Bureau during the past fiscal year. In accordance with a previous arrangement, one delegate each from the Physikalisch-Technische Reichsanstalt of Germany, the National Physical Laboratory of England, and the Laboratoire Central d'Electricite of France, came to Washington on April 1, and in cooperation with representatives of the Bureau of Standards carried out, during the months of April and May, 1910, a careful series of experiments on the silver voltameter and a considerable number of measurements on the standard cells and standards of resistance, comparing the standard cells and resistance standards which had been brought by the European delegates from their own laboratories with those of the Bureau of Standards, and with one another, and also comparing the different types of silver voltameters which have been used in the several countries. As a result of this investigation an agreement was reached with respect to the numerical value for the Weston normal cell, which is to be recommended to the International Committee on Electrical Units and Standards, and which it is hoped will shortly be adopted by all the civilized countries of the world. This will secure for the first time international uniformity to a high degree of precision in the three fundamental electrical units, namely, the ohm, the volt, and the ampere.

Preparatory to this international investigation, the Bureau carried on during the nine months preceding April 1 last an extended investigation into the silver voltameter and continued previous work on the standard cell.

RESISTANCE AND ELECTROMOTIVE FORCE.

The work on the conductivity and temperature coefficient of copper, undertaken at the request of the American Institute of Electrical Engineers, has been carried on during the year and is nearly completed and will very shortly be published.

INDUCTANCE AND CAPACITY AND ABSOLUTE MEASUREMENTS.

The work on the absolute measurement of electric current, which has been in progress for two or three years, is now nearly completed. This is a very fundamental as well as difficult investigation, and the importance of the results fully justify the considerable time that has been expended upon it.

An extended investigation into the properties of mica condensers used as standards of capacity has been completed during the year, and some work done on the use of relatively high frequency in electrical measurements.

ELECTRICAL MEASURING INSTRUMENTS.

In addition to the regular work of checking electrical instruments of standard types, the Bureau has made a comparative test of alternating current watt-hour meters from the leading makers of this country. This test covered the performance of the meters under normal conditions, and also under various combinations of abnormal conditions such as would be liable to occur in practice. The work was done at the request of the War Department. At the request of this same department the Bureau has conducted a comparative test of direct-current switchboard ammeters and voltmeters from eight American manufacturers. This work is nearly completed. Other special tests have been made for the general supply committee, other Government departments, and the public.

The design of two special electrical testing instruments was completed, and the instruments were built for the Bureau and are now in use. These instruments effect a marked saving of time in the accurate measurement of electric current, voltage, and power, and several of them have been purchased from the maker by the public in advance of a published description.

A circular on the "Testing of electrical measuring instruments" was prepared, summarizing the principles of operation of such instruments, sources of error, methods of checking, and other matter of interest to the user, and was widely distributed among central station companies.

MAGNETIC MEASUREMENTS.

The magnetic section began the year with well-defined methods of measurements of magnetic permeability and iron losses which gave consistent and, it is believed, accurate results. The permeability

determinations, however, were not in accord with those obtained elsewhere. With a view to locating the source of these discrepancies an intercomparison with several of the large commercial and university laboratories of this country was undertaken. From the data thus obtained, several common sources of error in commercial instruments were discovered and the cooperation of the commercial interests has been secured, looking toward better uniformity in magnetic measurements.

Smaller differences in the permeability determinations were noted in the work of foreign laboratories. For the purpose of securing international agreement, a number of standard bars have been prepared and measured, and sent to three national laboratories of Europe for their investigation. Experiments on the variation of permeability with changes in room temperature have shown that the temperature must be defined in precise work. A standard temperature of 25°C . has been adopted, and the apparatus is kept in an oil bath at this temperature. As a result of improvements in manipulation, the time required for a test has been notably reduced.

Investigations have been made on the strength and uniformity of the magnetic fields of electrical measuring instruments.

PHOTOMETRY.

During the year the Bureau has inspected and tested the incandescent lamps which have been used in all departments of the Government. These lamps, amounting to nearly a million carbon-filament lamps, besides a considerable number of high-efficiency metal-filament lamps, are purchased by the departments jointly, thereby securing lower prices and facilitating the inspection and testing of the lamps.

As has been done annually for several years, the standard specifications for incandescent lamps were again revised and republished at the end of the past fiscal year. These standard specifications are recognized by all manufacturers, and have brought about a uniformity in the manufacture of lamps which is very much to the advantage of both makers and users.

A considerable amount of work was done during the year in the preparation of carbon-filament incandescent lamps to be used as photometric standards. This involves, first, the selection and seasoning of the lamps so that they are suitable for standards, and, second, the determination of their candlepower when carrying a certain definite current at a particular voltage. The facilities of the Bureau for photometric work of highest precision have been somewhat improved, as described in two papers recently prepared for the Bulletin.

The investigation of photometric standards for gas photometry has been in progress during the year, a large amount of work having been done, including many measurements of pentane and Hefner

lamps, and a study of the possibilities of using a kerosene oil lamp as a secondary photometric standard. A study has also been made of problems involved in the testing of illuminating gas.

STANDARDIZING ELECTRICAL PRACTICE IN MINES.

A little more than a year ago the Bureau was invited by the officers of the American Mining Congress to assist the congress by taking up an investigation of the use of electricity in mines, with a view to standardizing electrical machines and electrical practice in mines. This work was carried on for a short time in connection with one of the committees of the American Mining Congress, and has since been continued by the Bureau independently, with the assistance, however, of a large number of mine operators, mine engineers, mine inspectors, and representatives of the manufacturers of electrical machinery used in mines. A study was made of the laws regulating the use of electricity in mines in various foreign countries and of the rules which are in force in this country, although very few States have laws or rules on this subject. A digest of the existing laws and a proposed code suitable for enactment into law, which have been prepared as a result of a year's work on this subject, have been published by the Bureau and sent to those interested in the subject. Suggestions and criticisms will be received, and the code of rules revised as further experience and study may show the necessity for revision.

DIVISION II.—LENGTH MEASUREMENTS.

About 550 length measures of various types have been tested during the year, of which about 425 were for the National or State Governments. Of these, 390 were steel and invar tapes, and the other items included a number of level rods, several calipers and meter bars, and large lathe screws tested for the Frankfort Arsenal to determine the accuracy of the machine that was used in making them. Other length measures tested for the public include several yard and meter bars, cement sieves, micrometers, micrometer gauges and calipers, steel roller balls, and a sector disk. A larger number of the invar tapes have been tested than heretofore, there having been 34 submitted for determination of their length, coefficient of expansion, or both. Some of these tapes which have been tested on the geodetic comparator before indicated a large change of length, one of them having shortened about 2.5 mm. As such changes practically destroy the usefulness of invar for base measuring purposes, unless they can be eliminated with certainty by special treatment, it is important that the causes of the changes be investigated.

MEASUREMENTS OF MASS.

An interesting feature of the year's work was the testing of the troy pound of the mint. This weight, for many years the fundamental standard of the United States for all purposes, was procured from England in 1827 and has been preserved ever since at the Philadelphia Mint. The apparent change from the value given in 1827 was only 0.005 grain and indicates a remarkable constancy in 83 years. Another test of special interest was that of a set of platinum weights below 1 gram, which had been calibrated at the Physikalisch-Technische Reichsanstalt of Germany and brought to this country in connection with the work on the fundamental electrical standards. The corrections obtained here agreed with those of the Reichsanstalt to within a few thousandths of a milligram. These differences are of about the same magnitude as those observed in previous tests of these weights made in Germany, and furnish another illustration of the extremely close agreement that has been attained among the standards of those countries which refer their weights to the international kilogram. The readjustment of standards that are not sufficiently accurate is usually left to the manufacturers, and standards found unsatisfactory either in structure or in precision have been returned to the manufacturer. During the past year, however, an unusually large number of cases have occurred in which it seemed advisable for the Bureau to do this work. The work has ranged from a set of very high grade standards for a well-known manufacturer of weights and balances to some of the rougher grades of "test weights" used by a city sealer. Aside from this larger amount of adjusting, the routine testing has been very nearly the same as during the preceding year. Some urgently needed standards for work of moderate accuracy have been prepared, and an opportunity was thus offered to test the efficiency of nickel plating for this class of weights. These have been tested several times and have proved to be very consistent. The fact that the surface of the nickel steel needs no protection against oxidization is a great advantage.

HYDROMETRY.

Provision has been contemplated for increasing the equipment for hydrometric work, and the necessary additional standards for extending its usefulness will soon be delivered. An investigation of the density and thermal expansion of alcohol and of its mixtures with water has been undertaken for the purpose of revising the inaccurate tables now in use as a basis of alcoholometry by density measurement. This has had the attention of one investigator for nearly a year, but

considering their value to the arts, and the fact that about \$200,000,000 of revenue is collected on the basis of such tables, the preparation of the new tables is of vital importance.

VOLUMETRIC MEASUREMENTS.

The demands in this work have increased about 50 per cent over the preceding year, and while the quality and accuracy of the volumetric apparatus submitted have shown a progressive improvement it is not as yet satisfactory. During the year a total of 20,512 pieces were examined, of which 6,178 pieces, or 30 per cent, were rejected by inspection on account of defects in construction, while 1,614 pieces, or 11 per cent, of those actually tested for capacity were found inaccurate. Ninety per cent of this work was done for the United States Government, nearly all of such apparatus purchased by the departments being submitted to this Bureau for approval.

About 56 capacity measures of metal or paper have been tested during the year, of which 14 were standards for the States of Massachusetts and Kansas, while the others included a cubic-foot bottle and a number of liquid and dry standards for manufacturers and city governments. The interest in the subject of weights and measures has resulted in an unusual number of demands on the Bureau for tests of rough standards used in ordinary commercial transactions. In some cases the fees which the Bureau is obliged to charge, combined with the express charges, amount to more than the original cost of the standards, emphasizing the need of local inspection in all parts of the country.

TIME MEASUREMENTS.

The watch tests in progress at the beginning of the year were finished, and the watches returned to the manufacturers with the results. The data obtained from these tests will be used in preparing a circular on the subject of watch testing. Accurate time was furnished to other divisions of the Bureau by the Riefler clock, which was frequently compared with the standard of the Naval Observatory. The most important time service was furnished in connection with the investigation of the silver coulometer, by the International Electrical Commission, and in connection with the calorimetric work of the Heat Division. Owing to the fact that the Navy Department made some changes in the character of the signals sent out by the navy-yard wireless sending station, it has been necessary to make the clock comparisons by telephone, a method which is unreliable on account of the introduction in the observations of the personal equation of the observer. A comparative test of about six of the most prominent clock systems suitable for installation in public buildings is being undertaken for the Supervising Architect of

the Treasury Department. A program has been arranged for the test, and the systems are now being installed at the Bureau.

ANNUAL CONFERENCE ON WEIGHTS AND MEASURES.

The Fifth Annual Conference on Weights and Measures, held at this Bureau in February, was better attended than any previously held, having 21 delegates representing the several States. Gratifying progress in protecting the public from the use of fraudulent weights and measures was reported by the delegates from all sections of the country, the steps taken to accomplish this result being the enactment of State legislation, the passing of new ordinances by cities, and the appointment of the proper officials under these laws and ordinances. The necessity of national legislation similar to the pure-food legislation, to unify methods of inspection throughout the country, was urged by the delegates, as well as legislation to correct abuses in interstate transactions. A resolution was adopted favoring legislation by Congress to require that all containers be plainly marked so as to indicate their net contents. It was also the opinion of the conference, expressed in a resolution, that authority to pass on types of weighing and measuring devices used in trade should be conferred on the Bureau of Standards by Congress.

DIVISION III.—THERMOMETRY, PYROMETRY, AND HEAT MEASUREMENTS.

The work in thermometry, pyrometry, and heat measurements during the year included 13,082 clinical thermometers, 1,508 laboratory and special thermometers, including a large number of calorimetric and Beckmann thermometers requiring the highest attainable accuracy, 7 optical and radiation pyrometers, 13 platinum resistance thermometers, 16 thermoelectric pyrometers, 2 pneumatic pyrometers, 58 standard heat samples, 17 lubricating oils, and 24 miscellaneous heat tests, such as the melting points of refractories, and similar tests.

The results of the following investigations were published in the Bulletin of the Bureau during the year: (a) The specific heats of calcium chloride brines in the interval -35° to $+20^{\circ}$ C., containing data of importance in refrigeration engineering; (b) the application of optical and radiation pyrometers to the measurement of the temperature of molten metals, a problem of importance in foundry work; (c) the use of platinum resistance thermometers at high temperatures and their application to the determination of the melting and freezing points of a number of pure metals obtained from different sources, with a view to establishing a series of fixed points or calibration temperatures and determining the accuracy with which such points can

be reproduced when metals, furnished as chemically pure by different makers, are used; (*d*) the determination of the boiling points of naphthalene and benzophene, with a view to throwing some light on existing uncertainties in the temperature scale, and for use as convenient fixed points in thermometry; (*e*) a consideration of the properties of an ideal gas; (*f*) a discussion of the theory of the Hampson liquefier, as a preliminary step in the construction of a more efficient apparatus for the liquefaction of gases.

A considerable number of standard heat samples (pure cane sugar) were furnished during the year to chemists and engineers for use in the standardization of combustion calorimeters. Very considerable progress has been made on the preparation and the determination of the heats of combustion of other substances, so that the Bureau will soon be in a position to issue a number of different standard heat samples, thus enabling the engineer to obtain a number of independent checks on the accuracy of his work. This work has materially assisted in introducing uniformity in the results of tests made by industrial chemists and engineers, and on which large fuel contracts are based.

A complete set of calorimeters representing the leading types of instruments used in the gas industries in this country and abroad have been installed during the year, and the completion of the investigations now in progress will enable the Bureau to furnish valuable information as to the necessary precautions that must be observed and the order of accuracy that is attainable in the use of these calorimeters when applied to different gases.

The assembling, design, and construction of nearly all the apparatus required for the determination of the heats of combustion of the more important constituents of illuminating and fuel gases has been completed. The completion of this investigation will enable the Bureau to issue a table of the more important constants of gases for the use of gas engineers.

Much of the apparatus required for the Joule-Kelvin porous plug experiment has been constructed in the instrument shops of the Bureau during the year, so that the more important parts of the equipment required for this work have now been assembled.

Considerable work has been done during the year with the electrically heated carbon-tube vacuum furnace, including the determination of the melting points of refractory materials. A special furnace has been designed for the determination of the properties of materials, such as thermal and electrical conductivity and melting points, at the highest attainable temperatures.

DIVISION IV.—OPTICS.

During the year a number of investigations have been completed in this division. In addition, there was 1,360 tests made largely for the departments of the Government. A new method for meas-

uring the relative wave lengths of light with high precision and facility was devised at the Bureau, apparatus constructed, and a preliminary investigation completed.

SPECTROSCOPY.

The testing done by this section has more than doubled during the year, and there has been an increase of tests of optical glass, photographic lenses, standardizing plates for refractometers, and the number of spectroscopic tests. The importance of having available light sources of definite intensity at all wave lengths has led the Bureau to investigate such sources. Many vacuum tubes of hydrogen, argon, and helium have been prepared at the Bureau, and their radiation has been studied in terms of the energy consumed and the density of the gas, and results of such investigations are of wide interest and usefulness in numerous technical fields. During the year a careful investigation of the results of the luminosity to temperature was completed and the results published.

This section has continued its cooperation with chemists in making difficult analyses and has advised many intending purchasers of optical instruments. Several weeks' time was occupied in assisting in an investigation of the effect of the light of mercury vapor lamps on eyes and vision.

RADIOMETRY.

During the first part of this year considerable time was spent in constructing a new vacuum bolometer and in remodeling the spectrometric apparatus. Several series of spectral radiation curves were obtained, from which some of the radiation constants have been computed. From a series of 14 spectral energy curves obtained with the new vacuum bolometer a tentative value of $T=2944$ has been obtained. This gives a value of $C_2=14600$. This is the most important problem in radiation at the present time. With each new improvement in the apparatus, the work becomes more reliable, and with the present apparatus it is hoped that quite high precision may be obtained. This involves either the reduction of humidity in the laboratory, which at present renders work impossible, or putting the complete optical system in vacuo at present.

The research on the reflecting power of metals has been completed. This had for its object the exact determination of the spectral reflecting power of various metals, including tungsten, tantalum, and molybdenum, which are of commercial importance in incandescent lamps. The results obtained offer a complete and convincing proof that the high luminous efficiency of these incandescent lamps is due to their selective emission in the visible spectrum, caused by a low reflecting

power in this region of the spectrum, and by a high reflecting power in the infra-red.

A new radiometer and a new quartz spectrometer have been completed and found to be the most sensitive of the kind yet described. The short focus (3f) quartz spectrometer gives six times the intensity of the other spectroradiometric apparatus now in use.

The distribution of energy in the visible spectrum is being determined to ascertain the spectral energy curves of several standard sources of light operated under specified conditions. Weaker sources of radiation—e. g., fluorescent spectra—can then be compared spectrophotometrically or spectrophotographically against one of these standard sources, and their energy curves thus determined indirectly. This investigation is almost completed, and will fill a need both in this laboratory and in other scientific work.

POLARIMETRY.

Besides investigations in progress, 1,339 polarimetric tests were completed during the year. The polariscopic testing of imported sugars has been continued. As a result of the work of the Bureau in this direction, the differences in the results at the five principal sugar ports have been reduced to as low as 0.2 per cent, a concordance which is quite satisfactory.

The demand has continued for the standard samples of sugars of high purity. These are issued as standardized fuel samples for testing calorimeters and also as samples for determining the 100 per cent point of the saccharimeter scale. By means of these samples both classes of instruments may be tested by the user.

The basis for standardizing saccharimeters is now under investigation and satisfactory progress has been made. As the transactions of the sugar industry rest upon the readings of the saccharimeter, the basis of standardization is of prime importance. During the past year special apparatus has been devised for this work and highly pure sugars have been prepared from raw sugars from widely different sources and compared with the pure sugars of other investigators in this country and abroad.

DIVISION V.—CHEMISTRY.

The work of the Chemical Division has continued along much the same lines as during last year, though the increase in the force has permitted the development of several new lines of work. There has been considerable routine testing of materials supplied under the contracts of the general supply committee. Related to this work has been the testing of a large number of important reagents ordered in duplicate from two prominent dealers in chemicals. Other reagents

furnished by a third dealer have not conformed in all respects with the published analyses. The systematic reporting of such discrepancies to the manufacturers will result in greater care in the manufacture and increased accuracy in the analysis of reagents.

A large amount of platinum ware purchased by the division was found of unsatisfactory purity. The defects were in part remedied, but the experience will be used to induce American manufacturers of platinum to give a reliable guaranty of the actual character of the material furnished instead of the misleading and indefinite statement that it is "of the best quality."

In this connection it may be stated that the division is always interested and cooperates whenever possible in all movements looking to higher standards of excellence of all materials whose value depends largely upon their chemical nature and purity. For example, the division is in close cooperation with the American Chemical Society, being represented on its special committees, such as the committee on specifications for rubber goods, the committee on the nomenclature of inorganic compounds, and the committee on the analysis of fats and oils; and the committee having general oversight of the various special committees of that society.

This division has aided in the work on the silver coulometer and on the Weston and Clark standard cells; has prepared alcohol of a high degree of purity for an important investigation undertaken by the Division of Weights and Measures; and has prepared a large number of substances which are being investigated as standards for calorimetry, in which connection a large generator for the electrolytic production of oxygen was devised and completed. It has also assisted in the photometric work by preparing pure substances for use in the standard lamps and studying the effect of impurities in these substances and also in illuminating gas.

The demand for the analyzed and certified standard samples of iron and steel is still increasing, the number distributed having been 717 against 687 for the year before. Two new Bessemer steel standards have been issued and renewals of two of the basic open-hearth samples are being prepared. A vanadium steel is about to be issued and a chrome-vanadium and a nickel steel await the completion of a special mixing machine which has been designed and is being built at the Bureau. There has been such a demand for the original standard irons that renewals of three of them have been prepared in large quantity. By a special device the fine graphite powder is removed so that the samples are more uniform and reliable, and have been commented on favorably by many to whom they have been sent. The Washington Navy Yard undertook the preparation of the ingots for the iron samples, which is a very special operation to prevent segregation. A manganese ore and three iron ores have been

added to the list of standard samples. A red cast-brass standard has been prepared, but not yet in sufficient amount to meet the probable demand, and a method of preparing sheet-brass samples has been worked out and material will soon be available for distribution.

In connection with the preparation of the standard samples of steel, methods for the more exact determination of vanadium and nickel have been worked out and will be published in the Bulletin. A study has also been made of the variations in the moisture content of the finely powdered ores adopted as standards. These variations, due to changes in the atmospheric humidity, have been shown to be large enough to cause serious discrepancies in exact analytical work, unless great care is taken to properly dehydrate the material. The varying moisture content of certain phosphate rocks was also studied in this connection.

Numerous samples of argillaceous limestone and of zinc ore have been distributed. During the coming year, the division will cooperate in the exact analysis of a standard sample of phosphate rock.

In response to numerous suggestions and requests from various quarters that the Bureau furnish standards for volumetric analysis, the division is endeavoring to obtain sodium oxalate of satisfactory quality for such use.

During the year there were completed about 1,757 tests and analyses, which may be classified as follows: (1) Printing inks, paper, mucilage, pastes, and sealing wax, 1,511, of which 1,437 were paper samples; (2) metals, especially type metal and similar alloys, 30; (3) reagents, 116; (4) paints, oils, and greases, 35; (5) rubber hose, valves, etc., 26; (6) miscellaneous, as submarine cable, book cloths, bricks, fertilizers, etc., 39. Among these tests are included the cooperative analysis of linseed oils and fertilizers and a critical study of a proposed method for the analysis of zinc ore concentrates. A tentative method for the determination of the suitability of gas-engine cylinder oils was devised and further work is still in progress. The preparation of materials for the determination of the atomic weight of bromine is well advanced and it is hoped that the research will be completed within a year. A new method for the determination of gum arabic in mucilages is well in hand and progress is being made in the study of the hydrolysis of different paper pulps. New methods for the detection of pitting in galvanized iron and tin plate and in tinned copper wires have been worked out. Different methods for the determination of rubber have been tested, and a new method for the determination of total and free sulphur was devised.

ENGINEERING INSTRUMENTS AND MATERIALS.

The apparatus and equipment for the testing and investigation of engineering instruments and structural engineering, and miscellaneous materials, has been installed in the new laboratories. During

the year 4,460 tests were made by this division, including engineering instruments and materials, papers, textiles, and miscellaneous materials.

The 100,000-pound universal testing machine, after installation in its new quarters, was carefully readjusted, calibrated, and found accurate and reliable. A 1,000,000-pound Riehle crushing machine for making tests upon stone, brick, terra cotta, cement, concrete, and for the determination of moduli of elasticity of building materials and structural forms has been installed and is now in operation.

The large 2,300,000-pound Emery machine for the testing of full-sized structural members and shapes is rapidly approaching completion. The reenforced concrete foundation is in place and the main foundation is completed.

The number of tests of engineering instruments has quadrupled. These included pitometers, water-current meters, anemometers, manometers, pressure gauges, and paper testers. The total number of pieces of apparatus tested is 206 as against 52 for the previous year. The calibration of water-current meters has been undertaken at the rating station on Chevy Chase Lake established by the Geological Survey and transferred by that office to this Bureau at the beginning of the year. Many of the instruments belonging to the water resources branches of the Federal and State Governments and to hydraulic engineers have also been rated. The station has been altered and considerably improved by the addition of new equipment, including a new car and recording device. An investigation to establish a new composite curve for Price meters is now in progress.

During the year the laboratory made, at the request of the engineer of bridges of the District of Columbia, the determination of the strains in members at the top of the main towers of the bridge across Rock Creek on Calvert street, Washington, D. C., and the laboratory has cooperated with the engineering department of the Pittsburg and Lake Erie Railroad in making measurements to determine the distribution of the stresses in the members of the large cantilever bridge being constructed across the Ohio River at Beaver, Pa. This work has been undertaken for the purpose of investigating and developing a new method of determining the stresses and strains in large structural members and for verifying the formulas and constants used by engineers in computing the elements of design.

It has also conducted at the shops of one of the larger boiler works some careful measurements to determine the distribution of stresses in lap-welded boilers and to study the physical properties of some boiler material.

In addition to the regular equipment for the testing of cement, special permeability apparatus for the study of methods of waterproofing has been installed, and refrigeration closets for freezing tests

and special furnaces for fire tests of ceramic materials are being constructed. Apparatus for torsion, cold bending, alternating impact, alternating stress, and hardness tests have been installed, and investigations are in progress.

The laboratory tests upon structural material have been both investigative and commercial. They have included tests upon steel, lead, aluminum, various alloys, cement, concrete, concrete reinforcement, brick, including sandlime, enamel, building, paving, and fire brick, terra-cotta chimney blocks, stone, etc. Much of this work has been done for the Government departments, among which are the Department of Justice, Superintendent of Capitol Building and Grounds, District of Columbia, Signal Corps, engineer of bridges of the District of Columbia, Panama Canal Commission, Reclamation Service, Ordnance Department, and Navy. The tests made for private parties were of an investigative nature, consisting of determination of the physical properties and suitability of new products.

The number of tests of miscellaneous materials, including paper, textiles, cordage, belting, belt lacing, rubber hose for air, steam, and water; gaskets, packing, lubricants, etc., has increased 20 per cent, and every Government department is included among those for which tests have been made. New equipment has been added to the paper and textile laboratories for investigations requisite to the preparation of standard specifications for Government materials and the development of uniformity in the standards used in the industries.

LIBRARY.

The library contains more than 5,000 accessioned volumes and some thousand pamphlets, for the most part on physics, chemistry, engineering, and related subjects. During the year 843 volumes were accessioned and 234 scientific and technical periodicals were currently received—79 American and 155 foreign. Other libraries in Washington have freely loaned books to the Bureau; 360 have been borrowed from the Library of Congress and 65 from other libraries.

PUBLICATIONS.

Three Bulletins were issued during the year, comprising 21 technical papers, relating to standards and precision measurements, giving the results of researches and investigations conducted by the Bureau of Standards.

Four new Bureau circulars were published giving information as to methods of testing specifications for standards and measuring instruments and regulations in regard to their verification: Circular 19, "Standard density and volumetric tables;" Circular 20, "Testing of electrical measuring instruments;" Circular 21, "Precision meas-

urements of resistance of electromotive force;" Circular 22, "Standard specifications for transformers, oil-immersed, self-cooled, 60-cycle, 2,200 volts;" Circular 13, revised.

PERSONNEL.

The personnel of the Bureau, including the Director, as provided by Congress, for the past fiscal year, consisted of 135 persons, classified as follows:

Scientific force: One physicist, 1 chemist, 8 associate physicists, 2 associate chemists, 24 assistant physicists, 5 assistant chemists, 24 laboratory assistants, 6 aids, 7 laboratory apprentices, and 2 laboratory helpers; total, 80.

Office and clerical force: One secretary, 1 librarian, 10 clerks, 1 storekeeper, 1 draftsman, 2 assistant messengers, 4 messenger boys; total, 20.

Engineer and mechanical force: One engineer, 4 assistant engineers, 2 electricians, 8 mechanics, 1 glassblower, 1 woodworker, 3 skilled laborers, 3 firemen, 1 elevator boy, 4 laborers, 2 watchmen, 2 janitors, 2 charwomen; total, 34.

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, 1910.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length.....	490	\$1,304.05	131	\$229.85	621	\$1,533.90
Mass.....	1,364	671.55	720	402.70	2,084	1,074.25
Capacity.....	15,036	4,490.25	236	141.50	15,272	4,631.75
Temperature.....	2,875	1,639.79	11,228	2,673.02	14,103	4,312.81
Optical.....	1,298	1,412.00	62	121.50	1,360	1,533.50
Engineering.....	4,854	9,753.35	103	234.75	4,957	9,988.10
Electrical.....	133	441.40	366	1,540.35	499	1,981.75
Photometry.....	4,913	11,133.90	353	666.60	5,266	11,800.50
Chemical.....	2,666	8,031.60	665	1,186.76	3,331	9,218.36
Hydrometry.....	927	979.95	68	108.50	995	1,088.45
Total.....	34,556	39,857.84	13,932	7,305.53	48,488	47,163.37

Besides the foregoing the Bureau inspected 935,480 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to \$5,058.01 additional, making the total value of work done for the Government \$44,915.85.

The number of tests made for the Government in the fiscal year 1910, exclusive of lamps inspected at factory, was 35 per cent greater than in the preceding year, and the number of tests for the public was 12 per cent greater, the increase in tests for both Government and public amounting to 27 per cent.

The receipts for tests were as follows:

Total receipts, 1910.....	\$6, 951. 89
Received prior to July 1, 1909, for tests completed in fiscal year 1910.	\$577. 21
Outstanding fees.....	136. 00
Refunds.....	8. 60
	<hr/> 721. 81
	7, 673. 70
Received for tests completed, fiscal year 1908-9.....	124. 40
Received for tests in progress at close of fiscal year 1909-10.....	243. 77
	<hr/> 368. 17
Fees for tests completed, 1909-10.....	7, 305. 53

FINANCIAL STATEMENT.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1910, 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, 1910:

Appropriation.	Total appro- priation.	Disburse- ment.	Liability.	Balance.
Salaries.....	\$165, 280. 00	\$160, 455. 01	.....	\$4, 824. 99
Equipment.....	46, 000. 00	34, 816. 83	\$10, 555. 20	627. 97
General expenses.....	17, 500. 00	14, 732. 29	2, 599. 27	168. 44
Grounds.....	3, 000. 00	2, 654. 57	335. 05	10. 38
Laboratory.....	175, 000. 00	172, 810. 01	.....	2, 189. 99
Testing machine.....	180, 000. 00	70, 420. 85	486. 84	109, 092. 31
Gaslight standards.....	10, 000. 00	8, 612. 83	1, 330. 17	57. 00
Weights and measures.....	10, 000. 00	6, 993. 76	811. 26	2, 194. 98
Freight truck.....	4, 000. 00	4, 000. 00	.....	.....
Total.....	610, 780. 00	475, 496. 15	16, 117. 79	119, 166. 06

The following statement shows the condition of the appropriations for the preceding two fiscal years at the close of business June 30, 1910:

Appropriation.	1908				1909			
	Total. appropriation.	Disburse- ment.	Liabil- ity.	Balance.	Total appropriation.	Disburse- ment.	Liabil- ity.	Balance.
Salaries.....	\$130,620.00	\$123,874.24	.....	\$6,745.76	\$141,540.00	\$138,765.11	.....	\$2,774.89
Equipment.....	41,000.00	40,525.50	.....	474.50	41,000.00	40,931.89	.....	68.11
General expenses..	15,000.00	14,929.98	.....	70.02	15,000.00	14,112.83	\$24.20	\$62.97
Grounds.....	3,000.00	2,983.56	.....	16.44	3,000.00	2,997.22	.....	2.78
Total	189,620.00	182,313.28	.....	7,306.72	200,540.00	196,807.05	24.20	3,708.75

Respectfully,

S. W. STRATTON, *Director.*

To Hon. CHARLES NAGEL,

Secretary of Commerce and Labor.

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