Annual Report

of the

Director of the Bureau of Standards

to the

Secretary of Commerce and Labor

for the

Fiscal Year Ended June 30, 1906

Washington
Government Printing Office
1906

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Department of Commerce and Labor

Document No. 74

BUREAU OF STANDARDS

REPORT

OF THE

DIRECTOR OF THE BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE AND LABOR,
BUREAU OF STANDARDS,
Washington, July 1, 1906.

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, 1906:

ELECTRICAL WORK.

The electrical division of the Bureau is divided into five principal sections. The first has to do with resistance and electromotive force, the second with inductance and capacity, the third with magnetism, the fourth with a wide range of electrical measuring instruments, and the fifth with photometry.

ELECTRICAL RESISTANCE AND ELECTROMOTIVE FORCE.

The work of this section includes the construction and verification of standards of electrical resistance and of electromotive force, the calibration of resistance boxes, Wheatstone bridges, potentiometers, and other resistance apparatus, the verification of resistance standards for current measurement, and the determination of the electrical conductivity, temperature coefficient, and thermoelectric power of materials.

The installation of the greater portion of the permanent equipment, especially designed to facilitate and expedite the routine testing of this section, has been completed. The standards of a number of manufacturers of electrical apparatus have been verified or reverified, the conductivity standards of several manufacturers of copper wire have been submitted for certification, and a large amount of testing has been done for other bureaus of the Government and for the public.

In conjunction with the chemical division, considerable progress has been made on the problems relating to the standard cell. A large number of cells set up with materials prepared by various methods

have been kept under observation in electrically controlled thermostatic baths, and the results indicate that they may be reproduced with a high order of accuracy.

Some progress has been made on the problem of the primary mercurial resistance standard in the construction of special comparing apparatus. A room will be fitted up so that measurements, as far as possible, can be made at 0° C, in accordance with the recommendation of the Berlin International Electrical Conference.

INDUCTANCE AND CAPACITY AND ABSOLUTE MEASUREMENTS.

This work includes the investigation of methods of inductance and capacity measurement, the construction and testing of standards of inductance and capacity for the Bureau, the testing of such standards for the public, and the measurement of the inductance and capacity instruments. Several important improvements have been made during the year in the accurate measurements of inductance and capacity, some of which have been described in the Bulletin of the Bureau. The standards of the Bureau have been further studied and their temperature coefficients investigated. The investigation which has for its object the determination of the ratio of the electromagnetic to the electrostatic units of electrical measure has been continued through the year, and results which are of much greater accuracy than have ever before been obtained have justified the large amount of work that has been expended upon this fundamental problem. The investigation will be described in forthcoming numbers of the Bulletin.

Condensers and inductance have been tested for educational institutions and the Government, including standards of capacity and inductance and instruments employed in wireless telegraph work.

MAGNETISM.

The work of this section has been unavoidably delayed by necessary changes in the personnel of the section. The development of the work will now be taken up and the Bureau will soon be in a position to do such magnetic testing as it is likely to be called upon to do.

ELECTRICAL MEASURING INSTRUMENTS.

In this section is carried on the investigation, and construction when necessary, of instruments of precision for measuring electrical current, electromotive force and power, and the phase, wave form, and frequency of alternating currents; also the testing of laboratory and commercial ammeters, voltmeters, wattmeters, watt-hour meters, phase meters, curve tracers, and other instruments used in connection with alternating currents. Several investigations have been made in connection with electrical measuring instruments, and a considerable amount of testing has been done.

During the year a considerable amount of apparatus has been added

and the facilities and conveniences of the laboratory increased by further wiring and switch-board connections. A special hot and cold room for use in measuring temperature coefficients has been built and considerable progress made in building a large rheostat and controlling switch for the 10,000-ampere battery used in heavy current testing.

A new form of potentiometer has been designed and built, and some of the new alternating current measuring instruments previously built have been thoroughly studied.

The harmonic alternator, especially designed and built for the work of this section, has been received and will soon be ready for use.

PHOTOMETRY.

During the year much progress has been made, both in photometric testing and in photometric investigation. A considerable number of incandescent lamps for use as secondary photometric standards have been standardized, including 50 such lamps to be used as standards at the various testing stations of the Navy Department. In addition, the demand for commercial testing of electric lamps for different Government Departments has developed so rapidly that the equipment recently installed for this work has already become inadequate, and additions will have to be made during the coming year.

Besides the tests on electric lamps, a study of the relative illuminating powers of a number of samples of oil was undertaken at the request of the Bureau of Corporations of this Department.

During the year a comparison of the photometric unit of the United States with the units of England, France, and Germany was undertaken, and preliminary steps were taken leading to a study of the question of primary standards of luminous intensity.

Apart from the testing of lamps and the study of photometric standards, it is the function of the section of photometry to pursue original investigation with a view to improving the methods of photometry. To this end an investigation of the rotating sectored disk, which was begun last year, was pursued further and completed during the present year, rendering possible the use of the rotating sector in the most accurate photometric measurements. Moreover, by the application of the sectored disk to commercial photometry, a saving of time has been effected and higher accuracy attained in this branch of the work.

The commercial photometer has been improved during the year by the addition of several new instruments, designed and constructed at the Bureau to meet the special needs of the work.

WEIGHTS AND MEASURES.

WEIGHTS.

The recomparison of the standards of mass, begun last year, was only partially completed, owing to the unusual amount of routine testing. A complete calibration has been made of the set of secondary

gold-plated standards, and it is expected that during the coming year the new set of platinum-iridium weights from 500 grams to 1 milligram will be intercompared and their values determined by direct comparison with the national prototype kilogram.

The effort on the part of the Bureau to improve the character of precision weights made in this country has been successful. They are now made in accordance with the specifications of the Bureau, and are equal to those made by the best European manufacturers. The circular recently issued, giving information as to the construction of weights, will lead to further improvement in their construction. There is an urgent and constant demand from manufacturers, State and city sealers, and scientific laboratories for weights bearing the seal of the Bureau.

The Bureau has adopted three classifications for weights, namely, A, B, and C, the classification depending upon their form, material, and adjustment.

Experiments have been made as to the effect of condensation of moisture on the surface of lacquered weights and will be continued during the coming year. This effect was found to be much greater than was anticipated, amounting to as much as one-tenth of a milligram in 50 grams.

MEASURES OF LENGTH.

The usual variety of length comparisons were made, including surveyors' and engineers' tapes, standard yards and meters, subdivided scales, plug gauges, deflection and inertia bars for magnetometers, and a number of special end standards. Satisfactory progress was made on the 50-meter comparator for geodetic standards and the 50-meter bench standard for tapes, both of which are installed in the tunnel connecting the physical and mechanical laboratories. In March the Coast and Geodetic Survey submitted a number of nickel steel (Invar) tapes which were needed for immediate use in the measurement of a number of primary base lines. In order to secure the range of temperature likely to be met with in the field, it was necessary to install a system of pipes through which cold brine may be pumped. By this means and by the introduction of hot air into the tunnel the temperature was varied from about +2° to +28° C.

The geodetic comparator, which will later be described in detail, consists of 11 stone piers, 5 meters apart, on which are mounted microscopes susceptible of adjustment in the vertical and horizontal direction. The distance between the microscopes is measured by means of a 5-meter bar, packed in ice to control its temperature, the bar and its ice trough being moved parallel to a line connecting the piers.

On account of the change in the distance between the terminal marks, caused by the expansion and contraction of the whole tunnel when the temperature was raised and lowered, it is difficult to determine how

accurately the distance between the terminal marks, 50 meters apart, can be determined, but there seems to be good evidence, based upon consecutive measures made about thirty minutes apart, that the probable error does not exceed 1 part in 5,000,000—a quantity far within that required.

Nonexpansible steel tapes are of recent construction, hence their behavior under working conditions is of considerable interest to the engineering profession. From the results obtained after repeated reeling and unreeling of the tapes and exposures to changes of temperature there is every reason to believe that their use in base-line measurement will increase the accuracy of such work and decrease the cost.

The determination of the constants of the Coast and Geodetic Survey tapes involved, also, a redetermination of the length of the 5-meter standards belonging to the Survey.

The construction of the 50-meter (150 feet) bench standard, mentioned in the last report, was completed in May, but it remains to be graduated. It was found impossible to get a bar of the required length, hence it became necessary to make the bar of shorter sections. After investigating the Goldschmidt thermit process, a number of cold rolled steel bars about 35 feet in length were purchased and welded together to form a bar slightly over 50 meters in length. The welding was entirely successful, resulting in a bar which is practically homogeneous and of the desired length.

The construction of the 1-meter comparator, though urgently needed, could not be taken up on account of the delay in securing a nonexpansible nickel steel I-beam, the essential feature of the proposed comparator. This material can be secured only in France, and great difficulty is met with in rolling it into beams of sufficient size. The microscope and piers are on hand and the necessary plans for the comparator are well under way. It will be designed to vary the temperature between 0° and 100° C and to maintain it constant at any temperature between the above limits by thermostatic regulation. When completed it is proposed to redetermine the relative lengths and absolute expansions of the national prototype meter and the secondary standards of the Bureau.

During the year a 50-foot bench standard installed in connection with the State sealer's office in the statehouse, Boston, Mass., was graduated by the Bureau, the necessary expenses being paid by the State of Massachusetts. The comparator, which was designed by the Bureau and partly constructed under its supervision, now forms a valuable addition to the equipment of the State sealer's office.

The comparator for end standards mentioned in the report of last year has been used with success during the year and proved to be all that was expected when it was designed. Lack of opportunity has

prevented a thorough investigation of the comparator, but a sufficient test was made to demonstrate that accurate results may be readily obtained.

A subdivided meter of the highest grade is urgently needed in this division, and steps have been taken to secure one of the platinum-iridium meters from the French Government, made of what is known as the "alloy of 1874." These bars were prepared by the French section of the International Committee on Weights and Measures, but were rejected by the International Committee because the impurities slightly exceeded those specified. Nevertheless four of those bars were made up and included in the comparison of the various national prototype meters, and proved to be in every way as satisfactory as those made from the material finally selected by the international committee. The bars in the present state are not subdivided, but if one is secured it could be graduated and afterwards sent to the International Bureau for calibration.

An Abbe Fizeau dilatometer for the determination of the expansion of small samples of metals will be added to our equipment, either by purchase or by construction in the shop of the Bureau.

VOLUMETRIC APPARATUS.

The greater proportion of the volumetric apparatus submitted for testing has come from the various laboratories of the Government Departments. Practically all apparatus of this character is purchased according to the specifications of this Bureau, and is submitted for test before acceptance by the Government.

There has been an earnest effort on the part of manufacturers of volumetric apparatus to comply with the requirements of the Bureau, and the effect of these regulations is already evident in the superiority of the apparatus now submitted over that formerly supplied on Government contracts. In order to assist manufacturers in improving the quality of the apparatus made by them, this Bureau has frequently undertaken the graduation of their standards; and in cases where important investigations have required apparatus more accurate than ordinarily made the graduation has been undertaken by the Bureau. Among these special cases may be mentioned measuring flasks for research work in sugar analysis and pipettes for the standardization of antitoxins. The apparatus designed at the Bureau for testing volumetric apparatus has been subjected to the practical test of routine work with practical results, and if the Bureau had the necessary assistance the demands for tests of this character could be promptly met.

HYDROMETERS.

The testing of hydrometers for various purposes has made good progress. This work has been done to a limited extent for a number of years, but within the past year it has reached a stage where it

becomes necessary to make a systematic study of the methods of hydrometry, including the investigation of the surface tensions of the liquids used in this work.

BAROMETERS.

A number of aneroid barometers have been submitted for examination and approval by different bureaus of the Government and by the public. This work is now done with an apparatus purchased from abroad, but which is inadequate. It is proposed to construct apparatus large enough to accommodate a greater number of instruments, and provide facilities for determining the effect of temperature on their readings.

MEASUREMENT OF TIME.

The Bureau continues to receive the noon signal from the United States Naval Observatory by wireless telegraphy, as mentioned in the previous report, and the standard Riefler clock, although exposed to considerable variations of temperature, furnished satisfactory time for Bureau purposes. The cabinet for testing watches in various positions has been completed, and a room, the temperature of which may be varied, is being fitted up for this purpose. Plans have also been prepared for converting a small room in the basement into a constant temperature clock room.

WEIGHTS AND MEASURES CONFERENCE.

The second annual meeting of the State sealers of weights and measures was held on April 12 and 13. The attendance and the interest displayed in the questions discussed were greater than at the first meeting. It was decided to form a permanent organization of State officials and others interested in weights and measures to hold an annual meeting for the purpose of discussing matters pertaining to the testing and sealing of commercial weights and measures throughout the country and to aid in securing the adoption of uniform laws in this regard. It was the general opinion of all present that if possible national legislation should be enacted relative to these questions. In order to secure the proper cooperation between the States and the Bureau, the Director of the Bureau was elected chairman and the chief of the weights and measures division of the Bureau was made the permanent secretary of the association. It was decided that at the next meeting a model law, to be prepared by the executive committee, should be presented for discussion. The effect of this organization toward bringing about much-needed reforms in the laws and practices concerning weights and measures will be very far-reaching.

THERMOMETRY, PYROMETRY, AND HEAT MEASUREMENTS.

The work carried out in this division during the year consisted in the testing of some 11,660 thermometers of various kinds, such as calorimetric and Beckmann thermometers used in determination of the calorific value of fuels, laboratory thermometers used for the precise measurement of temperatures up to 500° C (930° F), clinical thermometers used by the medical profession, maxima and minima thermometers, industrial thermometers for controlling the temperatures of technical processes, clinical standard thermometers used by manufacturers to control their product; also thermocouples, pyrometer-galvanometers, electrical resistance thermometers, and optical pyrometers for the measurement and control of high temperatures in metallurgical and other industrial operations and for special investigations in engineering laboratories. The calorific value of fuels has been determined as a basis for the award of contracts or the fulfillment of specifications for fuels furnished the Government. Tests have been made of the physical properties of illuminating and lubricating oils and other combustible compounds—such as the determination of the flash points, viscosities, setting points, etc.—and the testing of the thermal properties of glasses.

The results of an investigation of the methods of annealing high-temperature thermometers were published in Bulletin No. 2, Volume 2. This investigation called attention to the defects in high-temperature mercurial thermometers and suggested proper methods of heat treatment to avoid these defects. The result has been a marked improvement in the recent product submitted for test.

The 11,132 clinical thermometers tested were submitted by manufacturers, dealers, hospitals, physicians, and the several medical departments of the Government. Seven and five-tenths per cent of the clinical thermometers tested failed to pass the test requirements, in comparison with 8.4 per cent for the year preceding.

The intercomparison of the primary standard mercurial thermometers on which is based the standard scale of temperature in the interval 0° to 100° C—the interval in which the highest attainable precision in temperature measurement may be realized—has been practically completed, and it is expected the results will be published in the near future. Some new platinum resistance thermometers have been constructed, and a special Wheatstone bridge for platinum thermometer work has been provided with suitable accessories, such as thermostats, stirrers, thermoelectric keys, etc., for the rapid and accurate intercomparison of resistance thermometers, work on which this division is now engaged for the purpose of establishing the standard scale of temperature in the interval 100° to 500° C, and in the interval from 0° C down to the lowest attainable temperatures, which will soon be

available in connection with the liquid-air and liquid-hydrogen plant which is now practically installed.

The special calorimeter, cooling tank, differential resistance thermometers, and other apparatus required for the determination of the specific heat of brine solutions, an important thermal constant to the refrigeration industry, has been completed. The experimental work will be continued at every available opportunity.

Investigations have been carried out during the year on the radiation from platinum and palladium, and determinations of their melting points, important thermal constants in the higher pyrometric range, have been made. This work will be completed and published in the near future. In connection with this work a method has been developed which is especially adapted to the determination of the melting points of the rare elements concerning whose thermal constants practically no reliable data are at present available.

Progress has been made in a further study of radiation methods of measuring very high temperatures. The first publications bearing on this subject (Bull. No. 1, Vol. 1, p. 109; No. 2, Vol. 1, p. 189) have directed wide-spread attention to these methods, and many industrial plants, as well as engineering and research laboratories, are now applying them. In connection with this work a special investigation has been made on the degree of realization of black-body radiation from different kinds of radiators, a question fundamental to the study of all radiation problems.

A large amount of work has been done in the standardization of a number of thermocouples belonging to the Bureau. The measurements were most satisfactorily carried out with the aid of electric furnaces and at the solidifying points of a number of pure metals. On this work is based the standard scale of temperature in the interval 500° to 1,500° C. Comparisons with standard thermocouples that have been tested at foreign testing bureaus show a most satisfactory agreement at these high temperatures.

Consulting engineers, representatives of industrial plants and of engineering laboratories, have visited the Bureau during the year for the purpose of studying methods of high temperature measurement, and observing the operation of the various types of pyrometers in use in its laboratories.

As a result of the investigations carried out at the Bureau directing attention to the requirements of the industries in temperature measurement, several manufacturers have already, after consultation with the Bureau, brought out improved apparatus designed to meet these requirements. The information the Bureau has been able to place at the disposal of American manufacturers and engineers is an important feature of the work of this section.

It is of the utmost importance that the work relating to the intercomparison of the platinum resistance thermometers and the comparison of these with the primary standard mercurial thermometers be completed as early as possible, as the standard scale of temperature in use at the Bureau for the interval 100° to 500° C is based on this investigation. The Bureau is receiving many requests from engineering and scientific laboratories for temperature standards within this interval, in which the highest accuracy that is at present attainable in temperature measurement is of the utmost importance.

The importance of controlling temperatures in so many industrial operations and the demands of the recently developed electrochemical industries for the measurement of temperatures make it imperative that investigations should be carried out which would place at the disposal of the engineer and the investigator essential information as to the best methods of measuring these high temperatures.

As the gas thermometer is the fundamental standard of all temperature measurements, and as little reliable information is available concerning the gas scale of temperature above 1,150° C, it is especially desirable that a gas thermometer be constructed adapted to work at the highest temperatures to which this method is applicable, and that the scale which it defines be compared with the temperature scale obtained by other methods.

The facilities now available in the way of liquid air, liquid hydrogen, compressed gases, electrical energy, and apparatus especially designed for the measurement of small temperature differences with the highest attainable accuracy, imposes upon the Bureau the imperative duty of repeating and extending the classical experiments of Thomson and Joule on the expansion of gases, work which is fundamental to the whole conception of temperature.

The great demand for the testing of all kinds of temperature-measuring instruments has seriously retarded the progress of important investigations in this section, and it will be necessary to provide additional assistance at the earliest possible moment.

OPTICS.

While the work of this division consists chiefly in the determination of the properties of materials, physical laws, and constants, considerable testing has been done in polarimetry and a few in spectroscopy; investigations have been undertaken in connection with the application of interference methods to the measurement of length.

POLARIMETRY.

During the year special attention has been given to the work of clearing up certain doubtful points involved in the testing of raw sugars, both for the collection of duties by the Government and com-

mercial transactions. In order to accomplish this several theoretical problems have been undertaken, among which may be mentioned (1) a determination of the light source best suited as a standard; (2) the elimination of errors due to the clarifying reagent used in testing; and (3) the determination of the 100° Ventzke point on the saccharimeter scale. Much time has been spent in the perfecting of apparatus for the rapid and accurate testing of quartz control plates, necessitating an investigation of suitable monochromatic light sources. The work of eliminating the errors in the comparative daily exchange samples of sugar tested for the Treasury Department has been continued with good results.

SPECTROSCOPY.

The spectroscopic work of the Bureau has been directed toward the determination of the purity and intensity of sources of monochromatic light. The relation between the luminous intensity and energy intensity of radiation has been carefully investigated and applications made to monochromatic radiation. Many spectrum lines from different sources under different conditions have been examined in detail with an echelon grating and their structure and ratio of width to intensity recorded.

Four classes of requirements for monochromatic sources of light have been recognized and provided for:

1. Polarimetry requires sources of the highest possible intensity but of only moderate purity. The effect of both purity and intensity on polarimetric sensibility and accuracy was investigated theoretically and the most advantageous available light source determined.

2. Interferometry, as applied to measurements of length and angle, requires a high degree of purity but a moderate intensity. Limiting requirements were investigated and available monochromatic sources adapted to these requirements were determined.

3. Reference standard wave lengths require high purity and moderate intensity. Some attention was given to this field during the year; however, several thoroughly competent investigators have taken up the matter elsewhere.

4. Absolute length standards require the highest attainable purity with moderate intensity. The impurity should not exceed 1 part in 10,000,000. A source of this degree of purity was found and is being investigated.

RADIOMETRY.

During the past year an investigation of infra-red absorption and reflection spectra was undertaken and completed. The work included an examination of two classes of crystals, by a method which was developed from known facts concerning the selective absorption of heat rays. By this method it was shown that in one class of crystals the water content is present as water, while in the second class the

constituents of water are not present as such, but are chemically combined with other atoms.

A determination was made of the absolute reflecting power of a number of metals, which heretofore have not been examined. A preliminary examination of the infra-red selective reflection of solids in solution was made. The results obtained show that the method is feasible, and that the reflection spectrum of the solid may or may not be the same as when in solution. The field is entirely new and deserves further investigation.

A sensitive galvanometer, a bolometer, wire gratings, polarizing apparatus, and other accessories needed in infra-red radiometric work have been constructed in the instrument shop. Rock salt and sylvite prisms have been purchased, so that within a short time the equipment for this class of measurement will be fairly complete.

An investigation is in progress of the different types of instruments for measuring radiant energy, including the bolometer, radiometer, radio-micrometer, and thermopile. This includes also the development of a new instrument which is a combination of the radiometer and the radio-micrometer. A study of the radio-micrometer has shown that the weight of the moving coil can be reduced to at least one-third the weight of those previously described, while its sensitiveness is increased by at least 70 per cent by placing it in a vacuum.

CHEMISTRY.

During the year the samples of standardized irons, which have heretofore been distributed by the American Foundrymen's Association, were carefully analyzed at the Bureau, and in January the stock of those samples remaining in the hands of the association was turned over to the Bureau and since that time they have been distributed to parties desiring them.

One sample of standardized steel has also been prepared and is furnished in a similar manner, while arrangements have been partially completed for the preparation of a whole set of such standards.

A zinc ore, a sulphide ore, and a sample of bearing metal, which have been distributed by the different societies for the purpose of improving methods of technical analysis, have been carefully analyzed in this laboratory.

A considerable amount of work has been done in conjunction with the electrical division in the preparation and examination of pure material to be used in the construction of Clark and Weston standard cells.

A study of the standards of purity for chemical reagents and of the methods to be used for the quantitative determination of small amounts of impurities in such reagents has been undertaken.

A new determination of the exact quantitative relation between hydrogen and oxygen in water is in progress.

A number of substances have been examined for this Department partly in connection with contracts for purchases and partly in connection with investigations of the sale of commercial products which are being made by the Department.

ENGINEERING INSTRUMENTS AND MATERIALS.

This section is equipped to conduct tests of water meters not larger than 2 inches, gas meters and gas-meter provers, speed indicators, pressure and vacuum gauges, anemometers, and of paper, twine, and cloth. A large mercury manometer is now in the course of construction for the direct comparison of accurate pressure gauges and their study under varying conditions of temperature, pressure, and stability.

The demands upon the section for the testing of engineering materials have increased very much during the year. A limited amount of cement and concrete testing has been done for Government Departments and for the District of Columbia. Numerous cases of dispute regarding the quality of construction materials, such as iron, steel, brick, stone, cement, concrete, etc., have been referred to the Bureau for a determination of the physical properties in question.

The section is prepared to make extension, compression, and transverse tests on metals, to a total load of 100,000 pounds; to determine tensile and compressive strength, specific gravity and time of set of cement and cement mortars. The rapidly increasing use of concrete in construction work, especially in the form of hollow blocks, has developed a great need for the careful, independent, and exhaustive study of the thermal conductivity and the effects of temperature—more especially high temperature—upon the compressive strength, expansion, and durability of all kinds of concrete aggregate.

The use of concrete has developed a great activity in the production of high-grade building brick which shall be able to compete with it in compressive strength and durability. Requests for this kind of information are frequently referred to the Bureau and it is important that data be secured for the use of building inspectors and engineers. A special testing machine of large capacity is needed for this work in order that tests commensurate with actual working conditions may be undertaken.

There are in this country no uniform methods or apparatus for the testing of wood, paper, textile fabrics, inks, mucilage, etc. The development of standard methods and apparatus for this purpose, and the careful calibration of such apparatus for the Government Departments, large consumers, and manufacturers is an important work the Bureau ought to do.

The development of standard methods and apparatus for the testing of lubricating oils, oils used in the arts, resins, varnish, protective coatings, glue, etc., is also very important.

In order that this section may undertake the development of such standard methods and apparatus for the testing of the important materials of commerce, and assist in engineering researches which have a wide industrial significance, it is desired that additional space be provided by the erection, at an early date, of a building for this purpose.

PERSONNEL.

The personnel of the Bureau may be classed in three groups. The first has to do with the scientific work of the Bureau, the second with the office and clerical work, and the third with the operation of the mechanical plant, the construction of apparatus, and the care of the buildings and grounds. The plan of organization in each of these groups involves a regular graduation of salaries, in order that faithful and efficient service may be rewarded by promotion when vacancies occur.

In recommending persons for appointment to the staff of the Bureau every precaution is taken to insure that they possess the proper qualifications for the work in hand and the fundamental education or training necessary for advancement in the service.

The staff of the Bureau, including the Director, consists of 87 persons, distributed as follows:

Scientific force.—One physicist, 1 chemist, 4 associate physicists, 1 associate chemist, 9 assistant physicists, 2 assistant chemists, 16 laboratory assistants, 1 computer, 4 aids, and 6 laboratory apprentices; total, 45.

Office and clerical force.—One secretary, 1 librarian, 6 clerks, 1 storekeeper, 1 draftsman, 2 assistant messengers, 3 messenger boys; total, 15.

Engineer and mechanical force.—One engineer, 3 assistant engineers, 1 electrician, 6 mechanicians, 1 woodworker, 2 skilled laborers, 3 firemen, 1 elevator boy, 3 laborers, 2 watchmen, 1 janitor, and 2 charwomen; total, 26.

LIBRARY.

The library has been increased during the year by the addition of 713 volumes, in addition to numerous reprints and miscellaneous reports. These books are of a technical character, covering the work of the Bureau and subjects closely related to it.

The Bureau receives by subscription or exchange 118 scientific periodicals and proceedings of learned societies, and has received gratis many reports, translations, and bulletins from similar scientific institutions, universities, and learned societies. During the year 543 volumes, consisting mostly of this material and completed volumes of scientific journals, have been received and bound.

Purchases have been confined principally to books not available in other libraries of the city, or in such constant demand as to require

copies immediately at hand. The privileges of nearly all of the libraries of the city have been extended to the Bureau. Many books have been borrowed from them during the year, and much assistance has been rendered by the several librarians. The library has a complete author-and-subject catalogue of the works on hand. Through the card distribution of the Library of Congress the Bureau is enabled to complete its author-and-subject catalogue of the library collection as far as cards are printed on subjects relating to the work of the Bureau.

PUBLICATIONS.

The following publications were issued by the Bureau during the year:

Circular No. 3, concerning the verification of standards of mass.

Circular No. 9 (revised edition), regarding the testing and use of glass volumetric apparatus.

Circular No. 11, regarding the preparation and distribution of standardized samples of iron and steel.

The results of the scientific work of the Bureau are published in the form of bulletins, two of which were issued during the year.

A new edition of the table of equivalents between the metric and customary weights and measures has been issued.

A pamphlet describing the international metric system of weights and measures was issued in response to the demand for information upon this subject.

The report of the proceedings of the first conference on the weights and measures of the United States was also issued.

SUMMARY OF TESTS.

In connection with the work of the Bureau a certain amount of testing of standards and standard measuring instruments is done. The tests completed during the fiscal year are shown in the following table. In case the testing is done for parties other than the Government, fees are charged as provided for by law. For comparison, the corresponding amounts are also indicated for Government tests.

NUMBER AND VALUE OF TESTS COMPLETED DURING FISCAL YEAR ENDED JUNE 30, 1906.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length	181	$342.20	78	$134.90	259	$477.10
Mass	238	133.25	440	254.60	678	387.85
Capacity	923	261.80	11	10.25	934	272.05
Temperature	1,983	584.00	9,207	1,415.81	11,190	1,999.81
Optical	1,042	1,042.00	1	5.00	1,043	1,047.00
Engineering	403	1,748.00	25	40.00	428	1,788.00
Electrical	120	445.00	157	407.45	277	852.45
Photometry	1,130	344.30	42	47.50	1,172	391.80
Chemical	64	216.00	208	348.85	272	564.85
Sundries	158	121.50	186	176.00	344	297.50
Total	6,242	5,238.05	10,355	2,840.36	16,597	8,078.41

The receipts for tests were as follows:

Total receipts 1905–6		$3,055.81	
Previously received for tests in progress 1905–6	$62.75		
Due for outstanding tests	38.23		
		100.98	
			$3,156.79
Received for tests completed 1904–5		18.75	
Received for tests in progress		297.68	
			316.43
Fees for tests completed 1905–6			2,840.36

FINANCIAL STATEMENT.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1906, the disbursements 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, 1906:

APPROPRIATIONS, 1906.

Fiscal year ended June 30, 1906.

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$99,660.00	$95,723.45	$4.00	$3,932.55
Equipment	41,000.00	31,303.56	9,507.55	188.89
General expenses	12,500.00	10,640.83	1,612.03	247.14
Grounds	1,500.00	1,499.37		.63
Outbuildings	12,484.10	12,324.50	131.69	27.91
Total	167,144.10	151,491.71	11,255.27	4,397.12

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1906:

APPROPRIATIONS, 1904.

Fiscal year ended June 30, 1904.

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$74,700.00	$69,754.59		$4,945.41
Equipment	110,000.00	109,891.65		108.35
General expenses	10,825.33	10,722.79		102.54
Grounds	500.00	500.00		
Total	196,025.33	190,869.03		5,156.30

APPROPRIATIONS, 1905.

Fiscal year ended June 30, 1905.

Salaries	$85,780.00	$83,932.44		$1,847.56
Equipment	78,500.00	78,370.74	$50.00	79.26
General expenses	13,250.00	13,141.11	30.25	78.64
Grounds	1,000.00	1,000.00		
Outbuildings	15.90	15.90		
Total	178,545.90	176,460.19	80.25	2,005.46

INSTRUMENT SHOP.

The character and quantity of the work done at the Bureau is influenced largely by the facilities possessed for the construction of the special apparatus involved in all investigations. In every branch of testing, new and improved apparatus must be designed and constructed in order to increase the accuracy or reduce the cost. The instrument shop, while well equipped with machines and provided with several excellent workmen, can not meet the demands of the Bureau for its service. It is exceedingly important that several additional mechanicians be secured, one of whom should be a glass blower skilled in the construction of scientific apparatus.

BUILDINGS AND GROUNDS.

The small laboratory building designed for the work in low temperature, liquification of gases, and high pressure has been completed and much of the apparatus installed. This building is of substantial, fireproof construction and conforms with the others as to style and general appearance.

A few minor repairs and alterations were made to the buildings during the year, including the construction of a small tunnel under the west area of the mechanical laboratory which furnishes the means for running pipes and wires to the low temperature laboratory. The work of installing special piping, wiring, and plumbing in the several laboratories has progressed well during the year, but a considerable amount of this work remains to be done. The portion of the ground lying between the physical laboratory and the mechanical laboratory has been graded.

The steam and electric plant which furnishes heat, light, and power for the buildings and for laboratory use is no longer adequate for that purpose, and during the past year it has been necessary to keep it in operation during the greater part of the day. During the coming year it will be necessary to operate it continuously throughout the entire day of twenty-four hours. This will require some additional equipment and assistance in the engineering force.

Respectfully,

S. W. Stratton, *Director.*

The Secretary of Commerce and Labor.

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