ANNUAL REPORT

OF THE

DIRECTOR

OF THE

NATIONAL BUREAU OF STANDARDS

FOR THE

FISCAL YEAR ENDED JUNE 30, 1903

WASHINGTON
GOVERNMENT PRINTING OFFICE
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Treasury Department,

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National Bureau of Standards.

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TREASURY DEPARTMENT,
NATIONAL BUREAU OF STANDARDS,
Washington, D. C., June 30, 1903.

SIR: I have the honor to submit the following report of the operations of this Bureau for the fiscal year ended June 30, 1903. Under the act of February 14, 1903, this Bureau will be transferred July 1, 1903, to the Department of Commerce and Labor.

During the past fiscal year the work of the Bureau has been continued in temporary quarters pending the completion of the laboratory buildings now in process of construction. In addition to the fifteen rooms in the Butler and Coast Survey buildings occupied last year, the Bureau has also occupied during the year the residence at No. 235 New Jersey avenue SE. as a temporary laboratory.

The office and library of the Bureau, and laboratory rooms used for the work in connection with the testing of weights and measures, mercurial thermometry, photometry, and direct current electrical testing are in the Butler and Coast Survey buildings. The house at 235 New Jersey avenue has afforded accommodations for the instrument shop, dynamo, and storage-battery rooms, the laboratory rooms for beginning the work in alternating current measurements and in pyrometry. One of the new buildings (the mechanical laboratory) will be completed in September, and the installation of boilers, pumps, and steam piping is under way.

The planning of that portion of the mechanical and electrical equipment of the new laboratories not provided by the office of the Supervising Architect in connection with the building has been done during the year, and a part of this equipment has been ordered, including a tandem compound engine of 120-horsepower and two direct current dynamos to be directly connected to the engine (these will supply current for lighting, power, and experimental purposes during the next year); a second unit of equal size will be installed later; two storage batteries, each of 132 cells, and having a

capacity of 200 and 400 ampere hours, respectively, a double booster for charging the same; also three low voltage storage batteries for giving heavy current for special testing; four special alternating current testing sets, each consisting of either one or two alternators directly connected to a driving motor, for use in alternating current measurements and testing; an ammonia refrigerating machine of 30 tons capacity, for use in controlling laboratory temperatures, and a small ice-making plant which will furnish pure ice for experimental purposes. Specifications have also been prepared for the main switchboard of the engine room, for a gas plant, and for the automatic temperature-regulating system for the laboratories, and contracts therefor will shortly be awarded.

During the coming summer the engine, dynamos, switch board, storage batteries, refrigerating machine, gas machine, equipment of the instrument shop, and other machinery will be installed simultaneously with the plumbing, electric wiring, heating and ventilating apparatus, etc., in order that the building may be ready for occupancy early in the autumn. The experimental work to be done in this building will include the testing of direct and alternating current instruments, heavy current and high potential work; general photometric work, including the testing of arc and incandescent lamps; also the development of the testing of engineering instruments.

The physical laboratory, which was begun in March, will be completed during the coming year, hence the offices of the Bureau and the greater portion of the work now carried on in temporary quarters will necessarily be continued there for another year. The preliminary work necessary in the most important lines of work has been taken up in the temporary quarters, in order that the work of testing may begin promptly upon the completion of the new laboratory. In some cases this preliminary work is well advanced and considerable testing has already been done, as will be seen by reference to the tabulated statement at the end of this report. The demands made upon the Bureau, however, have been far in excess of its ability to meet them. Some of the original investigations necessary in order that the Bureau may properly perform its functions have been undertaken, but in general this work will of necessity be deferred until the completion of the physical laboratory.

The Bureau has frequently been called upon by manufacturers and scientists for information concerning standards, methods of measurement, and physical constants. It has endeavored in all cases to supply this information, and in many respects this is equally important with the comparison of standards or the testing of measuring instruments.

Numerous requests have been received from the manufacturers of scientific apparatus for the comparison of their standards with those adopted by the Bureau, for information concerning methods of construction and measurement, and for the testing of instruments of precision. Every effort has been made to encourage and assist the manufacturers of such apparatus.

PERSONNEL.

The limited number of positions provided for by the act establishing the Bureau was only sufficient to begin the solution of the problems enumerated above. The list has been as follows, including the additional positions made available July 1, 1902:

The Director.

Scientific Division.—One physicist, two assistant physicists, five laboratory assistants, and two laborers.

Engineering Division.—One engineer, one assistant engineer, two mechanicians, one skilled laborer, and one watchman.

Office Division.—Secretary, two clerks, one storekeeper, one messenger, and one laborer.

WEIGHTS AND MEASURES.

The large number of requests made upon the Bureau for tests and comparisons in connection with weights, standards of length and capacity, has left little time for the organization of new work in this field or for any extensive investigations. A detailed statement of the testing done in this section will be found in connection with the record of tests at the end of this report.

The verification of standard bars and gauges for manufacturers of high-grade machinery and measuring tools has been taken up to a limited extent during the year. It will be possible to devote more time and attention to this most important work during the coming year, with the increased force and equipment at the disposal of the Bureau. In the case of the shorter

gauges submitted, the work has been done on a small Zeiss comparator, the scale of which has been carefully investigated and compared with two standard decimeter scales furnished by the International Bureau of Weights and Measures. This scale was also investigated at the Physikalisch-Technische Reichsanstalt. The three results are in accord and left no doubt as to the value of the scale. The larger gauges were directly referred to the national prototype meter. The method of calibrating the subdivisions of the bars was that developed by Hausen and used at the International Bureau of Weights and Measures.

A bench standard for testing steel tapes was designed for the use of the sealer of weights and measures of the State of Massachusetts. The same plan will also be furnished to one of the leading tape manufacturers and will be used to establish a 100-foot standard in the new Government building at Chicago, Ill. These plans will also be followed in the construction of the bench standard to be installed in connection with the laboratories of the Bureau.

Considerable progress has been made in designing a set of model weights and measures for the use of city and State inspectors. It is the purpose of the Bureau to furnish such model sets or drawings of such sets to manufacturers, in order that inspectors and others desiring standards of the highest utility may be enabled to secure them. Many of the different States have laws which call for the periodic inspection of the commercial weights and measures used within their boundaries, but owing largely to the inability of the proper officer to secure the necessary standards and apparatus needed to fulfill their duties, the laws are in most cases inoperative. In no other way can the Bureau do a greater service to the public than by assisting inspectors to secure the proper appliances for performing their duties and in drawing up regulations for their guidance and use.

Many requests have been received for information concerning weights and measures and the laws and practices concerning them in the United States, in our insular possessions, and in foreign countries. In many cases the complying with such requests involved much time and labor searching for information, which must in all cases be exact, since any information of this character is regarded as authoritative when supplied by the Bureau.

The organization of the work of testing chemical glassware has progressed as rapidly as could be expected. A number of bulb burettes for use in this work were constructed by the Whitall Tatum & Co., of Millville, N. J., together with a number of flasks which will be used in standardizing the burettes referred to. Some experiments were made to determine the accuracy with which such apparatus could be used, and upon this experience in connection with the regulation of the German weights and measures office for doing similar work, were based tentative regulations which were submitted to the American Chemical Society for criticism and advice. It is further proposed to submit the regulations to manufacturers of chemical glassware so that the Bureau will be informed as to the requirements of both makers and users of such apparatus.

The Bureau has acquired a complete set of Jena glass hydrometers capable of measuring density of from 0.6 to 2.0, and the first and most important requirement for improving the subject of density determination is thus secured. This question, which was referred to in the last annual report, is of the greatest importance to the customs and internal-revenue services, as well as to distillers, brewers, and manufacturers of chemicals, etc.

The laws relating to weights and measures in the several States and in our insular possessions were compiled during the latter part of the past year. This compilation has proven to be of great assistance in answering the many questions concerning the practice in regard to weights and measures in this country. They clearly show the necessity for more uniform State laws, or better still, the passage by Congress of acts that will make the practice in regard to weights and measures uniform throughout the country.

A number of valuable pieces of apparatus were acquired during the year, among which may be mentioned a dividing machine for graduating scales, and another for circles. Both of the machines were purchased from the Société Genevoise, Switzerland. The Bureau has also acquired by purchase from the same firm a nickel steel scale 1 meter in length, subdivided in millimeters. The value of the scale lies in exceedingly small coefficient of expansion of the material. The steel from which it is made contains about 36 per cent. nickel, and the coefficient of expansion is less than one-tenth that of ordinary steel.

The following is a brief summary of the comparisons of mass, length and capacity the Bureau is prepared to undertake at present:

Standard bars up to 10 feet or 5 meters, leveling rods, finely graduated scales, metal tapes up to 300 feet or 100 meters, limit gauges.

Weights from 0.01 grain to 50 pounds, or from 0.1 milligram to 20 kilograms.

Capacity measures from 1 fluid ounce to 10 gallons, or from 1 cubic centimeter to 40 liters.

Hydrometers with scales corresponding to densities from 0.60 to 2.00.

THERMOMETRY AND PYROMETRY.

The work in the field of temperature measurement during the past year has been chiefly directed toward the design, construction, and purchase when possible, of such apparatus as will enable the Bureau to test all kinds of temperature-measuring apparatus.

For scientific work requiring the highest attainable accuracy in the measurement of temperatures in the interval 0° to 100°, this Bureau is now in the possession of five Baudin thermometers of the highest perfection of workmanship, and eight Tonnelot thermometers, all of which have been carefully studied at the International Bureau of Weights and Measures, and thus serve to define the connection of the temperature scale used by this Bureau with the international scale of temperature of the hydrogen gas thermometer. The Bureau has further prepared specifications and is now having constructed by Richter, of Berlin, a number of primary standard mercurial thermometers that are to be carefully studied at and compared with the standards of the Physikalisch-Technische Reichsanstalt. These various standards will, in the near future, be carefully intercompared here, thus firmly establishing the relation between the scales of temperature now used in scientific work and throwing further light on the accuracy attainable in mercurial thermometry.

The comparison tank for the intercomparison and certification of mercurial thermometers in the interval 0° to 100°, which the Bureau is now prepared to do, has recently been completed in the instrument shop. This comparator, which provides for the comparison of thermometers in both a vertical and horizontal position, is designed to embody every facility for the rapid and accurate intercomparison of mercurial thermometers.

The organization of the work of testing clinical thermometers has advanced as rapidly as possible. A large number of these thermometers of different manufacture were tested to determine the accuracy of their readings, the time taken by the thermometer to assure the temperature of the bath, the reliability of the index, and many other points. The first tests made showed conclusively that many of these clinical thermometers read too high and were undoubtedly graduated according to erroneous standards. The manufacturers were notified of this fact and advised to send their standards to the Bureau for verification. This suggestion was adopted by all the more important manufacturers, with the result that the clinical thermometers recently submitted for test show a marked improvement in the magnitude of the errors. The alacrity with which the manufacturers availed themselves of the services of the Bureau in this respect and the subsequent interest manifested by them in regard to the progress of the work is conclusive evidence of their desire to make their thermometers accurate.

For temperatures in the interval — 30° C. to 0° C. the Bureau has several primary standard mercurial thermometers that have been studied at the International Bureau and several secondary standard toluene thermometers. A special comparison tank for work in this interval has been designed, and as soon as it can be completed in the shop the Bureau will be prepared to certify thermometers in this interval. The preliminary steps have been taken toward the extension of the scale of temperature down to that of liquid air. For this work the Bureau is now having constructed pentane and petroleum-ether thermometers, and is in the possession of a number of copper constantan thermo-couples and platinum thermometers.

Specifications have been prepared and primary standard mercurial thermometers are now being constructed by Niehle, of Berlin, and by Baudin, of Paris, for work in the interval 100° to 550°. These thermometers are being carefully studied at the Reichsanstalt and at the International Bureau, and when received will be carefully intercompared with the platinum resistance thermometers, which for the present define the gas scale of temperature to be used by this Bureau.

The specially designed platinum resistance thermometers have been constructed by the Cambridge Scientific Instrument Company, and have

just been received by this Bureau. A special Wheatstone bridge resistance box has been designed for use with these platinum thermometers and is now nearly completed. This box is designed to insure the highest accuracy and great rapidity of measurement.

The comparison baths for work in the interval 100° to 550° are now being designed and the necessary parts assembled, so that the Bureau will be in a position in the course of several months to certify thermometers up to 550° C.

For the testing of pyrometers in the interval 500° to 1,500° C. much of the necessary apparatus is now in hand. As standards the Bureau is in the possession of several platinum and platinum-rhodium thermo-couples, which have been compared with the standards of the Reichsanstalt, in addition to a number of thermo-couples from other sources, and as soon as these have been recalibrated and intercompared the Bureau will be in a position to certify pyrometers for the public. The platinum thermometers will also serve as standards up to 1,000° C. For the testing of pyrometers the Bureau has available several small gas furnaces, several electric furnaces with necessary regulating rheostats, two radiation pyrometers with an electrically heated "black body" for the calibration of radiation pyrometers, a specially designed potentiometer suitable for thermoelectric work, a Callendar recording pyrometer, etc. The installation of this apparatus and the equipment of the laboratory with the necessary facilities, circuits, switch boards, etc., is now under way.

Much of the preliminary work in the design of an air thermometer has been done.

A very thorough digest of the most important work done in the field of high-temperature measurement from 1830 to the present time has been prepared.

The Bureau is at present prepared to certify clinical thermometers, mercurial thermometers in the interval −30° C. (−22° F.) to +100° C. (212° F.), and thermo-couples in the interval 0° to 1,500° C. (2,700° F.).

The necessary comparison baths for the intercomparison of thermometers in the interval 100° to 550° will be completed in the near future.

ELECTRICAL WORK.

The electrical work of the Bureau during the past year has been divided into two parts. The first has included the construction and verification of resistance standards and standards of electromotive force, the calibration of resistance boxes, Wheatstone bridges, potentiometers and other resistance apparatus, and the calibration of direct current measuring instruments and resistance standards for current measurement. In addition, facilities have been provided for the verification of photometric standards.

This work includes the following subjects:

(1) Primary and secondary mercurial standards and resistance standards of precision; (2) resistance boxes; (3) standards of electromotive force; (4) ammeter and voltmeter testing, and verification of resistance standards for current measurement; (5) photometry.

At present all resistance measurements of the Bureau are referred to a number of 1-ohm manganin standards, reverified from time to time at the Physikalisch-Technische Reichsanstalt, which are therefore known in terms of the primary mercurial standards of that institution. The construction of secondary mercurial standards is now under way. Experience indicates that such mercurial resistance standards are subject to considerable changes the first year or two after their construction, hence they will not be of any great assistance in fixing the standard of reference of the Bureau until the lapse of some time.

A considerable amount of work has been done in planning for the construction of the primary mercurial resistance standards. A supply of Jena glass tubing has been procured and subjected to a preliminary calibration, and a number of tubes of sufficiently uniform caliber and suitable cross section have been found, so that the final calibration can soon be undertaken.

The set of resistance standards of the Bureau has now been completed and consists of ten 1-ohm coils, and four coils of each of the following denominations: 10, 100, 1,000, 10,000, 100,000, 0.1, 0.01, 0.001, and 0.0001 ohms, together with two 2-ohm, three 3-ohm, two 5-ohm coils and two megohm boxes, so that there are on hand in most cases two reference

standards and two working standards of the same denomination. Two 0.00001 ohm standards are under construction.

Special importance has been attached to the accurate establishment of the ratios 1:10, 1:100, etc., upon which the values of the multiples and submultiples in terms of the unit depend; for the accurate measurement of resistance and for the establishment of the above ratios, a mercury contact Wheatstone bridge of the Anthony form was designed, and has just been delivered. For directly determining the ratio of two coils compared, a special box of ratio coils and four dial shunt boxes were designed. By means of the combination the ratio can be read off directly to parts in 1,000,000, the dials reading, respectively, 0.1, 0.01, 0.001, and 0.0001 per cent. Plans have also been drawn for apparatus based on the same principle for the rapid calibration of resistance boxes. A special Carey-Foster bridge is under construction by the Western Electrical Instrument Company, based upon designs submitted by the Bureau. During the year a considerable number of resistance standards have been compared, including the standards of the leading manufacturers of such apparatus.

The superiority of the Kelvin double-bridge method for the calibration of resistance boxes and other resistance apparatus has been thoroughly demonstrated, and all measurements, wherever possible, are thus made. In the near future comparisons can be made where necessary in a thermostatic bath, now under construction, of which the temperature can be accurately controlled. Investigations will be made upon the change in resistance of coils due to the heat developed by the test current.

The materials for a new lot of standard cells have been purchased from a number of leading manufacturers. The cells are to be set up in the immediate future. The special thermostatic bath referred to will be used for a redetermination of the ratio of the Clark and Weston standard cells, and for a redetermination of the temperature coefficients of each type. Special attention will be given to the preparation of mercurous sulphate with uniform electro-motive properties, and the purification of the materials employed. Arrangements have been made with the Weston Electrical Instrument Company for the loan of a dozen cells of the portable type, to

be used in determining the relation between the standard cells of the Bureau and those of the English and German institutions.

A laboratory has been equipped for the calibration of direct current ammeters, voltmeters, and wattmeters, and the verification of resistance standards for the measurement of very large currents. The present range is 600 amperes and 300 volts, but will be considerably extended in the near future. The resistance standard of lowest value of the Bureau is 0.0001 ohm. Standards of considerably smaller resistance can, however, be accurately calibrated. The double-bridge method is employed.

A laboratory has been equipped for the verification of photometric standards. No photometric testing has, however, been undertaken for the general public, pending the completion of a comparison of the standards in use by the manufacturers of incandescent lamps. Facilities for the verification of photometric standards and the investigation of the efficiency of arc lamps, incandescent lamps, as well as gas and oil lamps, will be provided as soon as the new laboratory, now nearing completion, is ready for occupancy. Investigations will also be made to develop a suitable primary photometric standard.

Facilities are now provided for the verification of resistance standards of precision and standard cells, the calibration of resistance boxes and other resistance apparatus, ammeters, voltmeters, wattmeters, watthour meters, the verification of resistance standards for current measurement, the determination of the electrical conductivity and the temperature coefficients of materials.

The second part of the electrical work has included the measurement of electrical inductances and capacities, and the testing of inductance coils and condensers, and the preparation for alternating current measurements of a wider range. For want of laboratory space, apparatus, and men this work has heretofore progressed slowly, but the increased force and enlarged facilities of the coming fiscal year will enable the work to be more rapidly developed.

A considerable quantity of apparatus has been received or ordered during the past year, and much time has been expended in designing

special alternating current generators, transformers, switchboards, and other machinery and apparatus, some of which has already been built and some is now building, while still other pieces are soon to be ordered.

The apparatus which has been received or ordered for use in this part of the electrical work includes a potentiometer, laboratory standard voltmeters, and standard shunts for measuring direct currents and voltages; a Kelvin double bridge, and several Wheatstone bridges, resistance boxes and rheostats, galvanometers, electrodynamometers, Kelvin balances, electrometers, and standard wattmeters for laboratory measurements of direct and alternating currents and electromotive forces; standard inductances and condensers; switchboard instruments of various kinds for direct and alternating currents; Helmholtz pendulum, chronographs, thermographs, barographs, hydrographs, and other recording instruments, together with a considerable quantity of auxiliary apparatus for experimental investigation. This apparatus has been purchased from the leading instrument makers of America and Europe. In addition, some pieces have been constructed in the instrument shop of this Bureau.

The Bureau is now prepared to measure the capacity of condensers by various methods, expressing it in terms of the standards of the Bureau, and to test condensers for leakage, absorption, and temperature coefficient. The Bureau is also prepared to measure inductances in terms of its standards, and will shortly be prepared to measure both inductances and capacities in absolute measure.

The calibration of alternating current voltmeters and ammeters will be begun in the near future, as well as the testing of alternating wattmeters and watthour meters, frequency indicators, phase indicators, and other alternating current apparatus.

THE OFFICE AND LIBRARY.

The work of the office division includes correspondence, the preparation of certificates, orders, accounts, records, library and archives, supplies, editorial work, and publications. The correspondence filing system has been further revised, the subject classification extended, and an improved method of indexing adopted. Orders for apparatus, supplies, etc., are placed upon requisitions signed by the chief of each section, and approved by the

Director, stating the articles required and their number. Orders are issued in triplicate, copies being retained for the office files and for the officer making requisition.

The work of the storekeeper includes the receipt and shipment of all articles ordered or received for testing, the entry at customs-house of all imported apparatus, the preparation of the inventory records and marking of apparatus with inventory numbers, and its delivery to the proper section of the Bureau.

The storekeeper's record consists of a record of the disposition of all supplies, and a card index of all the apparatus in the Bureau, one card being arranged serially by the inventory number assigned to the apparatus, and the duplicate index cards are classified by subjects. The office is also called upon to furnish stenographers and clerical services required by the scientific sections of the Bureau.

The library contains about 1,000 volumes. Twenty-six technical journals are regularly received at the Bureau. Fifty volumes of current journals were bound and placed in the library during the year. Printed cards are obtained from the Library of Congress, and a catalogue will be kept of all the books of that library in technology and physical sciences. The plans for the library are being considered with the new librarian, whose duties include the accession and classification of books, preparation of a simple card subject and author catalogues, purchase of the more important technical works in the various lines of the Bureau's work, and subscription to additional journals, securing sets of scientific reference books for the laboratories, the preparation of indexes, abstracts, and translations of current technical literature in subjects directly connected with the work of the Bureau.

The publications issued during the year include numerous record books and printed forms and the following documents: Annual Report of the Director for year ended June 30, 1902 (19 pages), issued February 19, 1903; Circular of Information No. 3, The Verification of Standards and Standard Measuring Instruments (4 pages), issued June 1, 1903; Circular of Information No. 4, Tables of Equivalents of the Customary and Metric Weights and Measures (38 pages).

NUMBER AND VALUE OF TESTS COMPLETED DURING FISCAL YEAR ENDED JUNE 30, 1903.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length	368	$130.90	111	$133.55	479	$264.45
Weight	291	345.00	109	100.25	400	445.25
Capacity	294	173.75	10	6.75	304	180.50
Photometry	1	2.50			1	2.50
Temperature	284	220.63	115	40.19	399	260.82
Electrical	13	71.00	56	172.50	69	243.50
Sundry	10	40.00	4	2.10	14	42.10
Total	1,261	983.78	405	455.34	1,666	1,439.12

Fees received 1902–3	$488.99
Fees for tests not completed during 1902–3	33.65
Fees for tests completed 1902–3	455.34

APPROPRIATIONS, 1901-2, CORRECTED TO JULY 1, 1903.

Appropriations.	Disbursements.	Liabilities.	Balance.	Total.
Laboratory	$69,249.95	$241,305.49	$14,444.56	$325,000.00
Site	25,000.00			25,000.00
Salaries, 1902	21,959.76		5,180.24	27,140.00
Equipment, 1902	8,440.44	1,500.00	59.56	10,000.00
General expenses, 1902	4,890.81	40.06	69.13	5,000.00
Total	129,540.96	242,845.55	19,753.49	392,140.00

APPROPRIATIONS, 1902-3.

Appropriations.	Disbursements.	Liabilities.	Balance.	Total.
Salaries, 1903	$32,559.93		$3,500.07	$36,060.00
Equipment, 1903	24,452.14	$5,498.59	49.27	30,000.00
General expenses, 1903	4,740.51	189.07	70.42	5,000.00
Total	61,752.58	5,687.66	3,619.76	71,060.00

Respectfully,

S. W. STRATTON, *Director.*

THE SECRETARY OF THE TREASURY.