SCIENCE

A WEEKLY JOURNAL DEVOTED TO THE ADVANCEMENT OF SCIENCE, PUBLISHING THE OFFICIAL NOTICES AND PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

FRIDAY, JUNE 24, 1904.

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THE ORGANIZATION AND WORK OF THE BUREAU OF STANDARDS.

THE Bureau of Standards was organized July 1, 1901, as one of the Bureaus of the Treasury Department, and Professor S. W. Stratton, of the Chicago University, was appointed director. On July 1, 1903, it was transferred along with certain other bureaus to the newly established Department of Commerce and Labor.

The functions of the Bureau of Standards are briefly stated in the act of congress by which it was established. The bureau is to acquire and construct when necessary copies of the standards adopted or recognized by the government, their multiples and subdivisions; to make accurate comparisons with these standards of instruments and standards employed in scientific investigations, engineering, manufacturing, commerce and educational institutions; to conduct researches pertaining to precision measurements and to determine the physical constants and properties of materials. The bureau is also to furnish such information concerning standards, methods of measurement, physical constants and the properties of materials as may be at its disposal, and is authorized to exercise its functions for the government of the United States, for state or municipal governments, for scientific societies, educational institutions, corporations, firms or individuals, and although not expressly authorized in the act referred to, sometimes also serves foreign governments. No fees are collected for services performed for the national or state governments. From others a reasonable fee is charged, and a

new schedule of fees has recently been published.

To carry out these functions adequately requires large, well-equipped and fully manned physical and chemical laboratories. To this end congress has appropriated $25,000 for a site, $325,000 for two buildings and $225,000 for apparatus and equipment. It is expected that the buildings will be finished and their equipment of apparatus and machinery installed during the present year. These buildings have been so planned and located that additional buildings may be added as they become necessary.

In the meantime, while the work of planning and building laboratories and designing and constructing the somewhat extensive and in many respects unique equipment of the same has been going on, the bureau has been effecting its organization and developing its work in temporary quarters. When the Bureau of Standards was organized it superseded the office of Standard Weights and Measures and acquired its equipment; the old offices in the Coast and Geodetic Survey building were retained, and by the courtesy of the superintendent of the Coast and Geodetic Survey, several additional rooms provided in the adjoining building. A year later a neighboring residence was rented and converted into a laboratory and instrument shop. In the brick stable at the rear of the house a gas-engine and dynamo were installed for charging a storage battery, the latter being located in the laundry; the kitchen became the carpenter and cabinet shop; in another basement room were installed a switchboard and several motor-driven alternators. The parlor and dining-room were taken for an instrument shop, and here four mechanicians and two apprentices turned out some very important pieces of apparatus, in most cases, of course, of special design that could not be purchased already made. The three floors above have been occupied as laboratories.

In these very inadequate quarters the bureau has not only gathered together a considerable equipment of apparatus and done a great deal of preliminary work, but it has also done some testing for the government and the public and not a little research. The quantity of testing done has been limited partly by an insufficient force of assistants, partly by the incomplete equipment of apparatus and partly by lack of space in which to set up apparatus already at hand. It is the intention to undertake nothing in the line of testing that can not be done well. In some cases, however, instruments and standards submitted have necessarily been retained a considerable length of time. In every case, however, the bureau has striven to complete all tests requested as promptly as consistent with satisfactory results. During the present preparatory stage of the bureau the time required is often much greater than will be the case after the work is well established.

THE ORGANIZATION AND PERSONNEL.

The act establishing the bureau provided for fourteen positions at an aggregate salary of $27,140. The next year (1902–3) the number was increased to twenty-four at an aggregate salary of $36,060. For the present fiscal year there are altogether in the bureau fifty-eight positions at an aggregate salary of $74,700. These positions are as follows:

One director, one physicist, one chemist	3
Eight assistant physicists, one assistant chemist	9
Fifteen laboratory assistants, one librarian, one computer, one draftsman	18
One secretary, four clerks, two messengers, one storekeeper	8
Four mechanicians, two woodworkers, three apprentices, two laborers	11

One engineer, one assistant engineer, one electrician, two firemen, two watchmen, one janitor, one charwoman..... 9

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Thirteen additional positions will be available for the next fiscal year. All positions in the bureau are filled through the civil service commission, in many cases as the result of special civil service examinations. An erroneous idea is more or less prevalent that even scientific appointments in the government are made on the basis of personal or political influence. Nothing could be further from the fact. The officers of the bureau have been free from any such pressure and in every case they have striven to select the best man that was available for any given position. These positions are permanent, the civil service commission affording ample protection against loss of position without sufficient cause. Thus, while the interests of the government are protected on the one hand, the interests of the servants of the government are guarded on the other; and while the machinery of selection sometimes seems ponderous and appointments are often considerably delayed, it would be difficult to conceive other methods that would accomplish what the civil service actually does accomplish without equally serious objections of one kind or another.

For convenience of administration the bureau has been divided into three divisions. Division I. is under the personal charge of the director; Division II. is under the charge of the writer; and Division III. is under the charge of the chemist, Professor W. A. Noyes.

DIVISION I.

Division I. comprises six sections, as follows:

1. *Weights and Measures,* under the charge of Mr. L. A. Fischer (Columbia University), who was for many years connected with the office of Standard Weights and Measures. He is assisted by L. G. Hoxton (University of Virginia), R. Y. Ferner (University of Wisconsin), N. S. Osborne (Michigan School of Mines) and L. L. Smith.

2. *Heat and Thermometry,* under the charge of Dr. C. W. Waidner (Johns Hopkins University), assisted by Dr. G. K. Burgess (M. I. T. and University of Paris) and Mr. H. C. Dickinson (Williams and Clark University).

3. *Light and Optical Instruments,* under the personal charge of the director, assisted by Dr. P. G. Nutting (University of California and Cornell) and Mr. F. J. Bates (University of Nebraska).

4. *Engineering Instruments,* under the charge of Mr. A. S. Merrill (M. I. T.).

5. *The Office,* under the charge of the secretary, Mr. Henry D. Hubbard (University of Chicago), assisted by Dr. J. R. Benton (Cornell), librarian, Mr. D. E. Douty (Clark University), storekeeper, four clerks and two messengers.

6. *The Instrument Shop,* with Mr. Oscar G. Lange, chief mechanician, and three other mechanicians and two apprentices, and the woodworking shop with two woodworkers.

DIVISION II.

Division II. comprises six sections, as follows:

1. *Resistance and Electromotive Force,* under the charge of Dr. F. A. Wolff (Johns Hopkins University), assisted by Mr. F. E. Cady (Massachusetts Institute of Technology) and Dr. G. W. Middlekauf (Johns Hopkins University).

2. *Magnetism and Absolute Measurement of Current,* under the charge of Dr. K. E. Guthe (University of Marburg, University of Michigan).

3. *Inductance and Capacity,* under the personal charge of the physicist, assisted by Dr. N. E. Dorsey (Johns Hopkins Uni-

versity) and Mr. F. W. Grover (Massachusetts Institute of Technology and Wesleyan).

4. *Electrical Measuring Instruments,* also under the personal charge of the physicist, assisted by Dr. M. G. Lloyd (University of Pennsylvania), H. B. Brooks (Ohio State University), C. E. Reid (Purdue) and F. S. Durston (Wesleyan).

5. *Photometry,* under the charge of Mr. E. P. Hyde (Johns Hopkins University).

6. *Engineering Plant,* under the charge of the engineer, Mr. C. F. Sponsler (Pennsylvania State College).

DIVISION III.

Division III. comprises the chemical work of the bureau. At present the personnel of this division includes, besides the chemist, only the assistant chemist, Dr. H. N. Stokes (Johns Hopkins University). This work is relatively late in its organization, for the reason that the bureau has no place in which to develop a chemical laboratory. Plans are being matured the present fiscal year, and as soon as the new buildings are ready a complete chemical laboratory will be installed in one of them.

Through the courtesy of President Remsen, Professor Noyes is doing some work this year in the chemical laboratory of Johns Hopkins University; and through the courtesy of Dr. Wiley, of the agricultural department, Dr. Stokes is doing some work in the chemical laboratory of the bureau of chemistry. We expect to see some additions to the chemical force at the beginning of the next fiscal year.

THE VISITING COMMITTEE.

In naming the personnel of the bureau, I must not omit to include the visiting committee, constituted as follows: President Ira Remsen, Johns Hopkins University; President Henry S. Pritchett, Massachusetts Institute of Technology; Professor Edward L. Nichols, Cornell University; Professor Elihu Thomson, Lynn, Massachusetts; Mr. Albert Ladd Colby, Metallurgical Engineer, Bethlehem, Pennsylvania.

These gentlemen meet in Washington at least once each year, and after receiving a report from the director, make a thorough examination of the work of the bureau. On the basis of this examination they present a report to the secretary of commerce and labor, making such recommendations as they think proper. This committee has already been of much service to the bureau, and it is believed that it will also serve a valuable purpose as a medium of communication between the scientific public and the bureau.

The director of the Bureau of Standards renders an annual report and submits his estimates of the needs of the bureau to the secretary of commerce and labor. Through him congress receives these estimates and grants specific sums for buildings, for equipment, for current expenses and for salaries, after the director has appeared before the appropriations committees of both houses and explained in detail the needs of the bureau and the work to be carried on with the money appropriated.

THE SCIENTIFIC WORK.

The scientific work and testing which the bureau is doing at present or for which preparations are in progress may now be briefly stated.

DIVISION I.

Section 1. *Weights and Measures,* including the determination of lengths, masses and volumes.

The bureau possesses at the present time two iridio-platinum copies of the international meter, to which all lengths are referred, and apparatus for comparing other bars with them. One of these standards was taken to Paris last year by Mr.

Fischer and recompared with the standards of the international bureau.

It will be remembered that in 1893 congress adopted the international meter as the fundamental unit of length, continuing the ratio of the yard to the meter as 36 to 39.37. At the same time the international kilogram was adopted as the fundamental unit of mass. Thus the old standard yard of 1840 and the troy pound of the mint of 1827 were superseded, and hence all measures of length and mass in either metric or English system are now referred to the international meter and kilogram.

We are at present prepared to determine the length of any standard from 1 decimeter to 50 meters, and also to calibrate the subdivisions of such standards and to determine the coefficient of expansion of the same for ordinary ranges of temperature. The bureau is also prepared at the present time to compare base-measuring apparatus and steel tapes, but the facilities are such that the best results are only attained at the expense of great labor.

The tunnel connecting the physical and mechanical laboratories will be fitted out with facilities for comparing this kind of apparatus. This tunnel will be 170 feet long, 7 feet wide and 8 feet high, and facilities will be provided for comparing tapes up to 50 meters in length and to lay out a base of the same length with an error not greater than one part in two or three million, over which base-measuring apparatus may be tested. Means will also be provided for raising the temperature to, say, 40° Centigrade, and lowering to 10° C., for the determination of temperature coefficients of apparatus submitted.

The bureau possesses two iridio-platinum copies of the international kilogram and also the necessary working standards to verify masses from 0.1 milligram to 20 kilograms. The balances now on hand include a series of the best American makes and one precision balance similar to those found at the International Bureau of Weights and Measures. These are to be supplemented by other precision balances now being constructed, and when the physical building is completed and the balances installed the determination of masses within the above-named range may be made with the highest degree of accuracy.

The determination of the density of solids and of liquids is also part of the work of this section. Two sets of Jena glass hydrometers, graduated to read densities directly from 0.6 to 2.0, and verified at the Normal-Aichungs Kommission of Berlin, form part of the newer apparatus of this section.

Capacity measures from 1 milliliter to 40 liters are being standardized, and plans are being made to test various kinds of chemical measuring apparatus in large quantities.

Aneroid barometers are also tested by this section, employing the very convenient apparatus designed by Dr. Hebe of the Reichsanstalt and used at that institution.

The bureau has also been called upon to advise the officers of state and city sealers of weights and measures regarding the proper equipment of those officers and the methods to be pursued in performing their functions.

SECTION 2. *Thermometry and Pyrometry.*—Facilities have now been provided for the testing of mercurial thermometers in the interval $-30°$ C. to $+550°$ C. The testing of toluene, petroleum-ether and pentane thermometers, and copper constantan thermocouples for low temperature work, will be undertaken in the near future, the range extending down to about $-200°$ C.

The standard scale of temperature adopted by this bureau for work in the interval $-30°$ to $+100°$ C. is the scale of the hydrogen gas thermometer, as defined

by the resolutions of the committee of the International Bureau of Weights and Measures, dated October 15, 1887. (This scale has now come into world-wide use, and its general adoption in all important scientific and technical work has contributed toward the solution of important questions bearing on the mechanical equivalent of heat and the international electrical units.)

As primary standards the bureau now has fifteen Tonnelot and Baudin thermometers that have been carefully studied at the international bureau and which are now undergoing further intercomparison here.

As primary standards, in the interval 100° to 600° C., Dr. Waidner has had constructed some specially designed platinum resistance thermometers, both of the compensated and potential lead type, together with resistance bridges and other apparatus designed to afford the highest accuracy and convenience in working. He has chosen the platinum resistance thermometer as the primary standard of the bureau because it defines a scale of temperature that is at any time reproducible in any part of the world, and unlike most standard scales, it is not locked up in a few instruments that have been directly compared with the gas thermometer. As secondary and working standards in this interval, 100° C. to 550° C., the bureau has a number of mercury thermometers constructed of French hard glass and of Jena borosilicate (59''') glass. Those intended for work above 300° C. have the space above the mercury filled with dry N or CO_2 gas under pressure. These mercurial standards are intercompared from time to time and occasionally they will be compared with the platinum resistance thermometers.

In the interval 0° C. to — 200° C. the standard scale of temperature is again that of the hydrogen-gas thermometer, and here also the platinum resistance thermometer serves to define the scale. For work in this range the resistance thermometer is, as before, referred to three known temperatures, viz., melting ice, melting CO_2, and the boiling point of liquid oxygen. As secondary and working standards in this interval, the bureau has a number of toluene thermometers, and copper-constantan thermocouples; and, in addition, some petroleum-ether and pentane thermometers, for use as low as — 180° C.

The scope of the testing work in this field, which is rapidly increasing, is already somewhat varied. It includes the certification of precision thermometers to be used in scientific work, the certification of standards used by some American thermometer makers, of thermometers used in important engineering tests, and of special types of mechanical thermometers used in industrial operations.

One branch of testing which promises to grow rapidly is the testing of clinical thermometers. Special apparatus has, therefore, been designed and constructed in the instrument shop of the bureau, to enable this work to be carried on with the greatest rapidity and precision. As an illustration of the results attained, it may be noted that 600 clinical thermometers can be read, at one temperature, in the space of 30 minutes.

Special facilities have been provided for high temperature testing, such as the standardization and testing of nearly all kinds of high temperature measuring instruments, including thermocouples, platinum resistance thermometers, expansion and optical pyrometers; the determination of the melting points of metals and alloys; the determination of the specific heats and coefficients of expansion at high temperature, etc.

Some of the apparatus has already been installed for the determination of the calorific value of fuels.

For carrying on this work the laboratory has been equipped with gas blast furnaces; electric furnaces which will maintain for hours temperatures as high as 1,400° or 1,500° C., constant to within a few degrees; electrically heated black bodies; and the necessary accessory apparatus, such as potentiometers, special resistance bridges, recording pyrometers, etc.

As primary standards for work in the interval 600° C. to 1,600° C., thermocouples obtained from various sources are used. These couples are referred to the scale of the nitrogen gas thermometer by measurement of their electromotive force at known temperatures, viz., the melting or freezing points of some of the metals.

The high temperature scale used by this bureau is based on the melting and freezing points of the metals as determined by Holborn and Day in their painstaking researches on the nitrogen gas thermometer. The scale is thus a reproduction of the high temperature scale used by the Physikalisch-Technische Reichsanstalt, and its adoption serves to extend the use of a uniform scale, which is always to be desired in physical measurements.

The establishment of our standard scales and the development of the apparatus required in testing have necessarily taken the greater part of the time since the establishment of the bureau. Research work has not, however, been neglected. The establishment of the standard scales has opened up a number of problems bearing on heat and temperature measurements, the investigation of which Dr. Waidner and Dr. Burgess have undertaken; this will form an important division of the work.

SECTION 3. *Light and Optical Instruments.*—The work of this section, which is under the personal charge of the director, has only recently been inaugurated, and it can not be fully developed until the second of the new buildings is occupied. Dr. Nutting is now carrying on some investigations on the electrical discharges in gases, to determine among other things the conditions necessary for producing a given spectrum by such a light source. Mr. Bates is making a careful study of polariscopic measurements, with special reference to the accurate determination of the percentage of pure sugar in a sample. The bureau has undertaken, at the request of the Treasury Department, to supervise the work of polariscopic analysis of sugar in all the custom houses of the country, and this is being done by Professor Noyes and Mr. Bates.

SECTION 4. *Engineering Instruments.*—The work to be undertaken in the near future in this section will include the testing of gas meters, water meters and pressure gauges, and testing the strength of materials, using for the latter work a 100,000-pound testing machine. Preparations for this work have only recently been begun, but the work is progressing rapidly. The range of the work will be extended beyond that indicated above as fast as possible.

DIVISION II.

Section 1. *Resistance and Electromotive Force.*—This work was begun by Dr. Wolff in the office of standard weights and measures several years before the Bureau of Standards was established. It was, therefore, the first section of the electrical work to do testing for the public and is now in a comparatively forward state of development. In addition to standard resistances and standard cells this laboratory also tests precision resistance boxes, Wheatstone bridges, potentiometers, precision shunts, etc. Specific resistances, temperature coefficients and thermo-electric properties of materials are also determined. A considerable part of the work of this section consists in the verification of apparatus of this kind for the other sections of the bureau.

For the present all resistance measurements of the bureau are referred to the mean of a number of one-ohm manganin standards which are reverified from time to time at the Physikalisch-Technische Reichsanstalt, and are, therefore, known in terms of the primary mercurial standards of that institution.

The construction of secondary mercurial standards, which after suitable aging change less than wire standards, has been begun and in time will be of service in fixing with the greatest possible accuracy the value of the one-ohm working standards. It is intended as soon as possible to construct a number of primary mercurial resistance standards. A supply of suitable Jena glass tubing has been secured, but the urgent demands upon the section for testing and the limited force available preclude this important piece of work for the present.

The set of manganin resistance standards of the bureau consists of ten one-ohm coils and four coils each of the following denominations: 10, 100, 1,000, 10,000, 100,000; .1, .01, .001, .0001, .00001, besides two two-ohm, three three-ohm, two five-ohm coils and two megohm boxes, this giving in most cases two reference standards and two working standards of each denomination.

Special efforts have been made to secure the accurate comparisons of the one-ohm coils with those of the other denominations, bearing the ratios of 1, 10, 100, etc. For this purpose as well as for the most accurate measurement of other resistances, Dr. Wolff designed and had constructed by Otto Wolff, of Berlin, a special mercury contact Wheatstone bridge of the Anthony form. For directly determining the ratio of two nearly equal coils Dr. Wolff had a special set of ratio coils and a four-dial shunt box constructed which enabled the ratio to be read off directly to parts in a million, the dials reading respectively .1 per cent., .01 per cent., .001 per cent. and .0001 per cent. Other special apparatus has been built or is under way for making precision measurements with a minimum of labor in the observations and computations.

The legal standard of electromotive force in the United States is the Clark cell, the value of which is 1.434 international volts at 15° C. and is, of course, the value used by the bureau. The Reichsanstalt uses a value nearly 0.1 per cent. smaller, namely, 1.4328. This unfortunate discrepancy can only be removed by further action of the next international congress followed by an act of congress if a change is authorized, fixing anew our legal standard. The value 1.433 is, perhaps, the nearest value that can be assigned from present data.

A considerable amount of testing has already been done by this section, chiefly resistance standards and resistance boxes, but including also a variety of other apparatus.

Section 2. *Magnetism and Absolute Measurement of Current.*—Preparations are under way for magnetic testing, but want of laboratory space has retarded the development of this work. Dr. Guthe is carrying on two important researches, namely, a study of the silver voltameter and a redetermination of the electrochemical equivalent of silver and of the absolute value of the Weston and Clark standard cells. A new absolute electrodynamometer is to be built for the latter investigation. The results of the investigation of the various forms of silver voltameters have recently been communicated to the American Physical Society. The magnetic laboratory is about to be established, and magnetic testing and research will be developed as rapidly as our limited force will permit.

Section 3. *Inductance and Capacity.*—A careful study of mica and paper con-

densers has been made, including the measurement of their capacities by different methods, the effect of time of charge upon their measured capacity, and the determination of absorption, leakage and temperature coefficients. Condensers have been purchased from various makers in England, France, Germany and America, and comparisons made with a view of determining the best performance to be obtained from both mica and paper condensers when used as measures of capacity. Some very interesting and valuable results have thus been obtained, although the work is not yet completed. Two large air condensers have recently been constructed to be used as standards. A new form of rotating commutator for use in determining capacities in absolute measure has recently been completed in our instrument shop and has been used in this work.

A considerable number of standards of inductance have been acquired and a great deal of work has been done in comparing inductances and determining their values absolutely. The bureau is now in a position to make accurate measures of both capacity and inductance and to compare and test condensers and inductance standards for the public.

SECTION 4. *Electrical Measuring Instruments.*—This section includes both alternating and direct current instruments (including instruments for measuring heavy current and high potential) except those precision instruments included in Section 1. Some testing of ammeters, voltmeters, wattmeters and watthour meters has been done for the public, but the principal work done so far has been preparatory. Many instruments have been purchased from the best instrument-makers at home and abroad, and other instruments have been designed and built in our own shop. Much of the apparatus purchased has been tested and in some cases altered and improved. Methods of measurement have been investigated, and a considerable experience acquired preparatory to the equipment of the laboratory for this work in the new building, to which this work has recently been transferred.

In addition to direct-current generators and storage batteries the following equipment of generators for alternating current has been acquired:

1. A small 120-cycle alternator, single-phase, suitable for voltmeter or condenser testing.

2. A three-phase 120-cycle alternator driven by an inverted rotary used as a motor and itself capable of giving a three-phase 60-cycle current.

3. A pair of 60-cycle three-phase revolving field alternators (direct-connected to a driving motor), of which one can have its armature rotated by a hand wheel while running, so that its current is displaced in one phase with respect to the other. Using one of these generators for the main current (which by use of transformers may be multiplied at reduced voltage) and the other for the potential current, any desired power factor may be obtained and wattmeters and watthour meters conveniently tested up to a capacity of 1,000 amperes and any desired voltage.

4. A pair of two-phase alternators, surface-wound and giving currents of nearly sine wave form (direct-connected to a driving motor), one alternator giving 60 cycles and the other 180, arranged so that the two armatures may be placed in series and the wave form varied through a considerable range by varying the magnitude and phase of the third harmonic. This is useful in studying the effects of varying wave form on the indications of measuring instruments of different kinds. For studying the effects of variations of frequency the speed can be varied through wide limits, and, for higher frequencies, the

higher frequency machine may be used alone. Transformers are arranged to change these two-phase currents to three-phase when desired.

5. Another three-machine set is under construction by the General Electric Co. This contains two 60-cycle three-phase alternators, with adjustable phase relation and surface windings, giving nearly sine wave form.

Special attention has been given to the matter of accurately measuring frequency, phase and wave form as well as alternating voltages, currents and power. These latter quantities are measured by means of instruments which admit of accurate calibration with direct currents and electromotive forces, the latter being measured by potentiometers, using standard resistances and Weston cells, the e.m.f. of the latter being of course known in terms of the standard Clark cells of the bureau. Thus all current, voltage and power measurements, both direct and alternating, are referred to standard resistances and standard cells.

The alternating instruments employed are as free as possible from errors due to inductance, eddy currents and capacity. Corrections are applied for the effects of small residual inductances when necessary. The alternating generators employed are driven by motors operated from storage batteries, enabling the speed and voltage to be maintained very uniform and measurements to be made with great precision. Thus frequency, voltage, power factor and wave form are controlled and varied as desired, and every effort is made to secure accurate measurements.

The bureau is now prepared to test alternating voltmeters, ammeters or dynamometers, wattmeters, watthour meters, phase and power factor meters, frequency indicators and other similar apparatus. Recently some very careful tests have been made on a lot of watthour meters to determine separately the effects of varying the voltage, frequency, power factor, temperature and wave form from the normal conditions, and of the load from 1 per cent. to 150 per cent. of normal full load, and curves plotted showing these several effects. As some of these effects were small, and as only one variable was altered at a time, very accurate measurements were required to determine the effects in question.

In the testing of direct-current instruments the bureau is now prepared to handle apparatus of capacities up to 1,000 amperes and 1,000 volts. A larger storage battery is being installed, which will give currents up to 5,000 amperes at 4 volts or 10,000 amperes at 2 volts, and a high potential battery of several thousand volts will be installed in the near future.

Section 5. *Photometry.*—One of the rooms of the temporary laboratory of the bureau was early assigned to photometric work, and an equipment of apparatus provided for measuring mean horizontal candle-power of incandescent lamps. The work was inaugurated by Dr. Wolff, but is now in charge of Mr. Hyde. As soon as the new buildings are occupied this equipment will be greatly augmented and the work enlarged. After doing considerable preliminary work the bureau is now prepared to test and certify incandescent lamps to be used as standards, and has already done this in a number of cases for manufacturers and others.

The Hefner amyl-acetate lamp has been somewhat generally accepted as a primary photometric standard, but its numerous defects make it quite unfit for a working standard. After taking the most elaborate precautions to maintain a steady and uniform flame, and applying corrections for the pressure and humidity of the air and its carbon dioxide content, the best results of the most skillful observers differ many

times more than in the comparisons of incandescent lamps of approximately equal efficiency with one another. Moreover, incandescent lamps suitably prepared and properly used are very permanent, and, being cheap and portable, may be duplicated and frequently tested. By keeping one set of lamps as reference standards and another as working standards, and burning them at relatively low temperatures (that is, at about four watts per candle), there is good reason for believing that the average value of a set of standards may be continued indefinitely.

A considerable number of electric standards have been obtained from the Reichsanstalt, the ratio of the candle to the Hefner unit being taken as 1 to .88. These reference standards are, of course, only occasionally used, and the mean of the value of several 16-candle power lamps is taken as the standard of the bureau. Exact copies of these will be added from time to time, so that of a change in any lamp is detected it may be discarded without impairing the completeness of the set. The current and voltage employed in testing lamps are measured by a potentiometer, and can be maintained constant to the hundredth of one per cent. Working by the substitution method, it is possible to make very accurate comparisons and thus to secure very exact copies of the standards of the bureau. The bureau recently requested a large number of lamp manufacturers to send each two or three carefully rated 16-candle power lamps for comparison with our standards. The lamps submitted varied from 15.4 to 17.6 candle power, averaging 16.48 cp., or about three per cent. high. Several of the large manufacturers were quite near to our standard, and it appears from these results that if all lamp manufacturers were to adopt the standards of the bureau there would be very little change in the average candle power of all the lamps manufactured, although some would be raised and others lowered. Since uniformity is extremely desirable and is now more easily attainable than heretofore, it is to be hoped that this result will speedily follow. The close agreement between the standards of the bureau and those of some of the manufacturers is due to the fact that the latter are using incandescent lamps rated at the Reichsanstalt. For the same reason, standards of the bureau are also in close agreement with those of the Lamp Testing Bureau of New York.

The purpose of the bureau is not to undertake, at least for the present, the commercial testing of incandescent lamps, but (apart from the testing done for the government) only to verify lamps to be used as standards and to make special investigations of lamps submitted for the purpose. To this end no effort will be spared to maintain reliable standards and to certify copies with the highest possible precision.

DIVISION III.

As already stated, the chemical division was late in being inaugurated. Aside from the immense assistance which a chemical laboratory can render to physical investigations, the division of chemistry will have important functions in its relations to the chemical interests of the country, and to the customs service and other departments of the government. Some chemical work is now being carried on, and detailed plans are being developed for the chemical laboratory to be installed in the larger of the two buildings now under construction.

THE EXPOSITION LABORATORY.

In addition to the exhibit which the bureau is making in the government building at St. Louis, it has undertaken, at the request of the authorities of the exposition, to install and operate an electrical testing laboratory in the electricity building dur-

ing the exposition. The work to be done will include the verification of measuring instruments to be used by the jury of awards in testing electrical machinery, and the testing for the jury of awards of instruments and apparatus submitted by exhibitors in competition. It is obvious that the intrinsic merits of a galvanometer, potentiometer, resistance standard, or other measuring instrument, can not be entirely determined by inspection, but only by rigorous test, and that a fully equipped testing laboratory can render important service to a jury of awards in the important and responsible duties which the latter is called upon to perform. A large exhibit of electrical instruments and machinery is expected from European manufacturers, more particularly from Germany, and without thoroughly testing the competing apparatus it would be impossible to distribute awards justly. It is proposed to publish the results of these tests so that they may be a permanent contribution to our knowledge of electrical instruments and machinery.

This laboratory is located along the east wall of the electricity building, south of the east entrance. The space assigned to it is nearly 200 feet long by 23 feet wide. A series of rooms have been constructed, all of which, except the office, are being equipped for laboratory purposes. A refrigerating machine having a capacity equivalent to the melting of ten tons of ice in twenty-four hours will be used in connection with the ventilating machinery and heat-regulating apparatus to control the temperature and humidity of the atmosphere in the laboratories. Piers and other substantial supports for apparatus have been installed and every effort is being made to provide the facilities and apparatus necessary to do precision testing.

In addition to doing the official testing for the jury of awards, testing for others will be done as far as practicable. For such work charges will be made according to the regular schedule of fees of the bureau. The laboratory will also serve as a working exhibit, and visitors will accordingly be admitted at certain specified times. For this reason, the exhibit of the bureau in the government building will be largely historical and educational and mainly devoted to subjects other than electricity.

EQUIPMENT OF THE BUREAU.

Some account of the proposed equipment of the new laboratories of the bureau has been published* in connection with the plans of the buildings, consequently no attempt will here be made to describe again either the buildings or their general equipment, or to go into detail regarding the equipment for any particular line of work. The intention of the bureau is to provide every facility necessary for experimental work, both for research and testing, and to have a sufficient force of engineers, firemen, electricians and other assistants so that the service may be available at any or all times. The instrument shop is already well established, and the expectation is to have it so well manned that any of the various sectional laboratories can be promptly served whenever the work of testing or research makes the services of a mechanician necessary. To do this will require a considerable increase over the present force. Indeed, it is likely to be several years before the personnel will be so far increased as to meet urgent requirements. Notwithstanding the considerable force of men now at work, the bureau is seriously in need of more clerks, mechanicians and laboratory assistants; besides research workers and men to inaugurate new work, who are also much needed.

It is needless to emphasize further the importance of the highest standards in all

* Science, January 23, 1903.

the work of the bureau. Every new line of work taken up means a new research, and often the designing and building of a new series of instruments. As the limits of errors are narrowed the labor is rapidly augmented. What one man might do well in a day may require two men a week or a month if the accuracy is to be considerably increased. This will explain why the bureau has not already announced a greater range of testing, and why even when both the new buildings are occupied many lines of work will remain to be inaugurated.

It is the constant purpose of the bureau to cooperate with instrument makers and manufacturers to the end that their output of instruments and apparatus may be improved. Not simply to certify errors or criticize results, but to assist in perfecting the product, is the aim. In this work the bureau has so far enjoyed the confidence and cooperation of manufacturers to a gratifying degree. It was largely to meet their needs that the bureau was organized, and if by serving them the standard of excellence of American-made instruments and machinery is raised, the bureau will have served the public also. In several specific instances a marked improvement of this kind is already seen, due directly to the influence of the bureau of standards.

The advantage to scientific men and engineers of having a place in this country where instruments and standards may be verified with the highest possible precision, and at nominal charges, and where researches may be undertaken when necessary to answer questions arising in such comparisons, is evident. It greatly facilitates precision work both in engineering and in research.

The bureau has also fulfilled another of the functions mentioned in the act authorizing its establishment, in furnishing information on a variety of subjects included more or less closely in its field of activities. A considerable correspondence of this kind has grown up.

The functions of the Bureau of Standards are very broad and its possibilities for usefulness correspondingly great. It should do in its field, indeed, what the Coast Survey and the Geological Survey and the Department of Agriculture are doing in theirs, and what the Physikalisch-Technische Reichsanstalt and the Normal-Aichungs Kommission are doing in Germany. Fully to realize these possibilities will of course require a much further increase in equipment and in personnel, and this we expect to see.

EDWARD B. ROSA.
NATIONAL BUREAU OF STANDARDS.

SCIENTIFIC BOOKS.

Christian Faith in an Age of Science. By WILLIAM NORTH RICE, Ph.D., LL.D., Professor of Geology in Wesleyan University. New York: A. C. Armstrong & Son. 1903. Pp. xi + 425.

As the author himself hints in his preface, it would not be difficult to cull some delightful antinomies from this work, and on a scale more extended than Dr. Rice suspects. At the same time, it was ever thus with books of the class. For example, I can picture the meaningful smile that would cross the faces of certain experts I could name, when they read those pronouncements: 'It is evident, in general, that we have in the book of Genesis nothing that approaches the character of reliable history till about the time of Abraham (p. 122); the Fourth Gospel is probably the only record by an eye-witness of the events connected with the resurrection' (p. 363). Similarly, in another field, when Dr. Rice suggests that the virgin birth and the resurrection—in the most usual acceptation of these terms—are essential to Christianity (p. 377), one is bound to refer him to the relative articles in 'The Encyclopædia Biblica.' In the same way, his naïve account of will would scarcely satisfy psychologists, while his fearfully and wonderfully made presentation of causality would amaze the thoroughly modern metaphysician.