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, FEBRUARY 3, 1905.

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MSS. intended for publication and books, etc., intended for review should be sent to the Editor of SCIENCE, Garrison-on-Hudson, N. Y.

*THE NATIONAL BUREAU OF STANDARDS AND ITS RELATION TO SCIENTIFIC AND TECHNICAL LABORATORIES.**

THE dedication of a large and well-appointed building to be devoted exclusively to instruction and research in physics is a notable event in the history of a college. In this instance it is the realization of a hope long cherished by many, and by none more than by the present speaker. That so splendid a building has been deemed necessary for the work to be done in physics suggests two things. First, the high standard which Wesleyan is setting for herself in this as in other departments of work, and, second, the rapid development which has occurred in recent years in physics, rendering imperative an equipment for experimental work of an entirely different order of magnitude from that thought sufficient a generation ago. So great has been the demand for the best instruments and standards to be used in experimental work, both in pure and in applied physics, that the government has been led to establish at Washington a national laboratory, one of whose functions is to cooperate with scientific and technical institutions and manufacturers in the work of improving instruments and standards and developing methods of measurement. It, therefore, seems not inappropriate that something be said on this occasion concerning this work of the national government, so recently in-

* An address delivered at the opening of the John Bell Scott Memorial Laboratory of Physical Science, at Wesleyan University, Middletown, Conn., December 7, 1904.

augurated as not to be generally known.

The bureau of standards was established by act of congress in response to a demand for such an institution on the part of many scientists, engineers, manufacturers and representatives of the national government. The high order of accuracy required in modern engineering practise and in scientific research made it more than ever necessary that manufacturers of scientific and engineering instruments should possess correct standards of length, mass and volume, as well as electrical, optical and thermometric standards, and be able to have them reverified from time to time. It was also important that any one engaged in scientific or engineering work could have his instruments and standards tested whenever necessary. The office of weights and measures, at Washington, had been equipped to do some of the work required in the verification of length, mass and volume for many years, but it was necessary to send electrical standards, thermometers and pyrometers and many other kinds of apparatus to Europe to be tested when results of the highest accuracy were desired. As this was both expensive and time consuming the consequence was that only infrequently were these more accurate tests obtained. The United States held a creditable position among the nations of the earth in physical science, and had some of the best physical laboratories in the world; it was leading the world in the manufacture of electrical machinery and some kinds of electrical instruments. To be obliged to ask the German imperial or other foreign laboratories to do our testing for us, because we lacked a well-equipped national laboratory for doing such work, was clearly a situation that ought to be corrected, and congress acted promptly when the importance of the matter was brought to its attention. Appropriations were made for laboratory buildings and equipment and for a director and a small scientific staff, and the bureau began its work July 1, 1901. President McKinley appointed as director Professor S. W. Stratton, of Chicago University, to whom more than to any one else is due the credit for the establishment and the success of the bureau. A careful study of the Physikalisch Technische Reichsanstalt and of other European laboratories was made in connection with the designing of the laboratory buildings and the selection of the equipment, and many valuable suggestions were derived therefrom. The laboratories have, however, been constructed after American rather than European models, although in their equipment it has been found necessary to draw very heavily upon European instrument makers.

The bureau began its work in temporary quarters and has been developing methods, building and acquiring apparatus and doing testing for the government and the public while the laboratory buildings have been under construction. The larger of the two buildings was only recently completed and the bureau is just now moving into it, the first building having been occupied nearly a year ago. We now find ourselves, about three and a half years from the organization of the bureau, in possession of buildings and equipment costing about $600,000, with a personnel carefully selected through the civil service and numbering altogether seventy-one, maintained by annual appropriations amounting to nearly $200,000, and, judged by the magnitude and importance of the output of testing and investigation, ranking second only to the great German Reichsanstalt among the government laboratories of the world doing this kind of work.

After this brief epitome of the history of the bureau let me state more particularly something of its work and of its relation to the scientific and technical laboratories of the country.

The work of the bureau may be briefly specified under three separate heads as follows:

1. To acquire and preserve standards of measure and to certify copies of the same, and to test and investigate measuring instruments and to determine the properties of materials.

2. To conduct researches and to investigate and develop methods of measurement; to improve instruments and apparatus for physical measurements and to devise new apparatus, especially for use in testing and in precise measurements.

3. To distribute information regarding instruments and standards to manufacturers, state and city sealers of weights and measures, scientific and technical laboratories, and to any and every one applying for such information.

These three functions of the bureau are closely interdependent. To acquire a standard in some cases involves an elaborate investigation and the independent determination of the value of the standard; and to preserve it may involve subsequent redeterminations of its value to ascertain whether any change has occurred. A new kind of test often involves the investigation of methods of measurement, or the determination of new standards or the construction of a new instrument. Thus research and testing are intimately connected in most of the work of the bureau.

The distribution of information, the third function of the bureau, is accomplished through correspondence and the circulars and bulletins issued by the bureau, and also by the personal visits of people seeking such information.

The three fundamental standards of measure are those of length, mass and time. The oldest of these is the unit of time, the second. This ancient unit has successfully withstood every attempt to replace it by a decimal submultiple of the day. The earth itself is our fundamental timepiece, every revolution upon its axis counting off 86,400 sidereal seconds, from which we immediately derive our standard second. No clock is so perfect a timepiece as the earth and all the standard clocks in the world are corrected by it. What the astronomer does in determining the time by astronomical observations, is to read off the time of day or night by means of a telescope on the starry face of the celestial clock. The telescope corresponds to the hour hand of a 24-hour dial (there is no minute hand), and the stars mark the subdivisions of the dial. The best made clocks of human invention go fast or slow by at least some fraction of a second each day, but there is no proof to show that the terrestrial clock deviates by so much in a thousand years. Thus the unit of time is a natural unit, easily obtained direct from nature and universally employed the world over.

The Bureau of Standards does not intend to make independent time observations, but will correct its standard clocks from the observations made at the neighboring Naval Observatory.

The unit of length has a very different history. The foot has been the most widely used measure of length, both in ancient and in modern times. It was derived, as the name suggests, from the length of the human foot and is thus a natural unit like the second; but, owing to the multiplicity of human feet and their varying dimensions, this unit has varied greatly in different countries and in different ages, its length ranging all the way from the ancient Welsh foot of nine inches to the Piedmont foot of twenty inches. In modern times it has varied from the Spanish foot of less than eleven inches to the Venice foot of over thirteen inches, almost every country using a foot of different length. The confusion resulting from this lack of uniformity prompted the French in 1799 to adopt a new unit of length, and remembering how surely and elegantly the unit of time is fixed by the rotation of the earth, they sought to make the meter, the new standard of length, permanent and inflexible by basing it upon the dimensions of the earth. The meter was chosen to be one ten-millionth part of the distance from the equator to the pole of the earth at a particular meridian, and was fixed in concrete form as the length of a platinum bar, which has been carefully preserved in Paris. Subsequent and more accurate measurements have given a slightly different value for the circumference of the earth, so that the meter is known not to be, as originally intended, just one ten-millionth of a particular quadrant of the earth. The meter has, however, not been changed, its value being fixed by the length of the platinum standard and not by the earth. Thus the platinum bar has become the primary standard of length, instead of a secondary standard as was originally intended. This is a happy result, for the difficulties of comparing a meter with the dimensions of the earth is too great to make the dimensions of the earth of any value as a standard of length. The original standard meter has been reproduced many times in platinum and iridio-platinum, and many of the civilized nations of the earth possess such duplicates. We have two of them at the bureau of standards in Washington, one of which was recently taken to Paris by Mr. Fischer, and recompared with the standards of the international bureau. The results showed almost perfect agreement with the comparison made fifteen years previously, the difference, if any, being not greater than about 0.5 of a micron, that is, 1/50,000 inch. This is one part in 2,000,000 of the length of the bar and represents about the limit of accuracy obtainable in comparisons of this nature, although the computed probable error of the observations was only .02 of one micron, or less than a millionth of an inch.

The third fundamental unit, that of mass, has likewise varied in different countries and in different ages. The most widely used unit was the pound, and before the metric system came into use there were hundreds of different pounds in use in Europe, differing from country to country and from province to province, and varying also according to the commodity to be measured. The ancient Roman pound was equivalent to a little less than twelve of our avoirdupois ounces, and from it were derived the various Italian pounds, varying in value from the Venice light pound, equivalent to about eleven of our avoirdupois ounces, and the Naples silk-pound and the Milan light pound of about twelve ounces to the Piedmont pound of about thirteen ounces and the Venice heavy pound of about seventeen ounces. There were silk pounds, and chocolate pounds, and table pounds, and goldsmith pounds and medicinal pounds; there were light pounds, and heavy pounds, and half-heavy pounds and extra-heavy pounds. There were pounds of 12, 14, 15, 16, 17, 18, 20, 21, 22, 24, 28, 30 and 36 ounces, and the ounces had varying values in different countries and in different provinces of the same country.

To remedy this distressing confusion the French, in 1799, at the same time the meter was chosen, adopted the kilogram as the unit of mass, fixing it concretely in a cylindrical mass of platinum, which was intended to be equal to the mass of a cubic decimeter of water at the temperature of its maximum density. This, like the meter, was designed to be a natural unit that could be derived originally at any subsequent time and in any country. But, as in the case of the meter, later determinations showed that the kilogram was not exactly equal to the mass of a cubic decimeter of water as was intended, and hence the platinum secondary standard was adopted as a primary standard of mass and no further attempt made to make it a natural unit. All other countries using the metric system use carefully constructed copies of this original kilogram as their standards of mass. The process of weighing is even more accurate than the comparison of lengths, so that the standard kilograms of the various countries of the world are practically perfect duplicates of the original and of each other.

In 1875 a conference of the representatives of seventeen nations was held in Paris and a permanent international bureau of weights and measures was established and is still maintained. It is located at Sèvres, near Paris, and is supported jointly by the participating nations. Its duties are to care for the fundamental standards of length and mass, to furnish accurately adjusted copies of the same, and to compare standards which may be returned from time to time. Some other testing is done, including the calibration of thermometers. The work is of the highest order of accuracy and leaves little to be desired so far as standards of length and mass are concerned. The metric system has been adopted by nearly all the civilized nations of the world, excepting Great Britain and her colonies and the United States, and is universally used throughout the world for scientific purposes. The electrical units are all based on the metric system and hence electrical engineers employ the metric system almost exclusively, even in this country. The gain to science and commerce due to the adoption of the metric system can scarcely be overestimated and it is to be hoped that it will soon be adopted by the English-speaking countries of the world.

The avoirdupois standard for the United States was defined in 1830 as 7000/5760 of the Troy standard pound of the mint, which in turn was a copy of the British Troy pound, derived from the standard of Queen Elizabeth made in 1588. The latter was derived from the standard of Edward III., and this is said to have come from the city of Troyes, France, hence the name, Troy pound. The metric system was legalized in the United States in 1866, and the meter was declared to be equivalent to 39.37 inches and the kilogram to 2.204 pounds. The international bureau began its work in 1879. The iridio-platinum prototypes of the metric standards were received in this country in 1889. These were so much superior as standards to the brass standard pound and the bronze yard, that in 1893 the metric standards were adopted as fundamental standards by the United States and the pound and yard were defined in terms of them. Thus the metric system is not only legalized in this country, but our fundamental standards are the meter and kilogram and all our weights and measures are derived from these metric standards using the legal equivalents.

Few people, perhaps, realize how needlessly complex our system of weights and measures really is. Instead of a single unit of weight and of length with multiples and submultiples having ratios of ten, and a unit of volume simply related to the unit of length, as is the case in the metric system, we have a multiplicity of units and all kinds of odd ratios for the multiples and submultiples. I beg your indulgence for a moment while I remind you of some of the absurdities of our system. But first recall how much simpler and more convenient our decimal coinage is than the English coinage. Nothing could be simpler than the expression of values in dollars and cents; the use of pounds, shillings and pence, to say nothing of guineas, crowns and farthings with their odd ratios, being cumbersome in comparison. But our weights and measures are far more cumbersome and complicated than the English coinage. We weigh most merchandise by avoirdupois weight, gold and silver by troy weight, medicines by apothecaries' weight, diamonds by diamond carat weight. We have dry quarts and liquid quarts, long tons and short tons, and a hundredweight is not 100, but 112 pounds. Coal is usually purchased at wholesale by the long ton and retailed by the short ton. A bushel sometimes means 2,150.4 cubic inches and sometimes it means a certain number of pounds weight of a commodity. The American bushel is derived from the old English Winchester bushel, but the legal English bushel of the present day is larger by 69 cubic inches. On the contrary, the English gallon is much larger than the American gallon, the difference amounting to about 20 per cent. We measure wood by the cord, stone by the perch, earth by the cubic yard. Moreover, among the different states of the union are considerable differences in custom and in legal equivalents. We are, of course, much better off than the countries of Europe were a century ago, but the difference is all too small.

Our medieval system of weights and measures is, however, too deeply rooted to be easily displaced. But the metric system is being used in this country more than is generally realized and our rapidly growing foreign trade is bringing it more than ever to the attention of merchants and manufacturers. In England a strong effort is being made to adopt the metric system, with the hope that ultimately a decimal system of currency may also be adopted. The English colonies are even more progressive than the mother country, and strong influences are at work to secure the decimal system throughout the British empire. It will be greatly to the advantage of the United States to keep abreast of this movement, and not to be the last among the civilized nations of the world to throw off the incubus of an incoherent system of weights and measures, whose chief claim lies in the fact that it is in general use.

The testing of lengths and masses constitutes one of the most important branches of the work of the bureau. As I have said, this work has been done by the government for many years, but the facilities for the work are being immensely improved by the bureau so as to extend the range and increase the accuracy of the work. The new laboratories will contain many new balances and comparators and every precaution is being taken to secure the most favorable conditions possible for precision work. When the installation is completed it will probably be the best of the kind in the world.

I have said that the three fundamental units of measure are those of length, mass and time, or the meter, kilogram and second. From these are systematically derived various other units, all forming what is often called the centimeter-gram-second system, or, more briefly, the c.g.s. system. It is not my purpose to enumerate the various derived units which are employed in scientific and technical work, but rather to describe briefly some of those employed in the testing and research work of the bureau. And first let me speak of the work in heat and thermometry. The testing of thermometers is one of the most important branches of the work of the bureau. This work is under the charge of Dr. Chas. W. Waidner, who is personally known to some of you. Dr. Waidner and his assistants have devoted a great deal of effort to the acquisition of reliable standard thermometers and to the investigation of instruments and methods. In this they have availed themselves of the results of the magnificent work that has been done in this field in Europe, more especially at the Bureau Internationale and the Reichsanstalt, and by the thermometer makers of France and Germany. For our present purpose thermometers may be conveniently grouped as follows: (1) Precision mercury thermometers, to be used as standards or for scientific purposes. They are calibrated very elaborately and are capable of high accuracy. (2) Ordinary mercury thermometers and clinical thermometers. We test clinical thermometers by the thousand and we hope before long that they will come to us by the tens of thousands. Clinical thermometers often change if graduated new, and hence they ought always to be aged, tested and certified to insure their accuracy. (3) High temperature mercury thermometers of hard glass, with nitrogen under pressure above the mercury column, reading up to 550° C. (or about 1000° F.). (4) Platinum resistance thermometers, thermocouples and other forms of pyrometers suitable for measuring furnace temperatures up to 1600° C. (about 2900° F.). Such instruments are used in many manufacturing processes, as well as in research problems and hence are found both in scientific and in technical laboratories. (5) Optical pyrometers for measuring the temperatures of the hottest furnaces and, approximately, even the temperature of the electric arc, the highest temperature attainable by any known means, namely, about 3950° C. (or 7150° F.). An investigation on this subject at the bureau has recently been published by Drs. Waidner and Burgess. (6) Low temperature thermometers, for temperatures below the freezing point of mercury, even down to the temperatures of liquid air and of liquid or solid hydrogen. Such thermometers use pentane or toluene; or a copper-constantan thermocouple is employed. For the very lowest temperatures helium gas is used, helium being the only gas not liquefied at the temperature of solid hydrogen, namely, about 16° above absolute zero, or 257° C. (or 430° F.) below the freezing point of water.

The bureau has done more or less testing in all these lines except the last, but hopes soon to add this to the list of tests which are made.

From the temperature of solid hydrogen to that of the electric arc is a wide range, indeed, and a very considerable equipment of apparatus and machinery is necessary to produce and to measure any temperature throughout this range. For the higher temperatures numerous gas and electric furnaces are required. For the lower temperatures a refrigerating plant and apparatus for liquefying carbon dioxide, air and hydrogen are required. The bureau has recently purchased the low temperature plant which was operated as an exhibit by the British government at the St. Louis Exposition. This was one of the most interesting exhibits of the entire world's fair. Liquid hydrogen was produced in larger quantity by this plant than had ever been done before, more being made and used in public demonstrations during the season than the total amount that has been produced since hydrogen was first liquefied. Solid hydrogen is also produced by the apparatus.

The optical work of the bureau is not so fully established as the work in weights and measures and heat and thermometry, but three well-trained specialists are devoting themselves to it and a fourth is soon to be appointed. The work of research and testing in this section, which has been taken up or is soon to be begun, includes the investigation of the optical properties of instruments and of materials; the application of interference and other optical methods to linear and angular measurements; the investigation of the spectra of vacuum tubes and other phenomena in connection with the passage of electricity through gases at reduced pressure; and the investigation of questions connected with the polariscopic analysis of sugar and the testing of polariscopes.

The latter subject is of special importance on account of the use of polariscopes in determining the duty on sugar imported into the United States. The bureau has undertaken, at the request of the Treasury Department, to supervise the work of polariscopic analysis of sugar in all the customhouses of the country. Sugar is the chief source of revenue among articles imported, the duties collected by the government amounting to over $60,000,000 per annum. The duty on each importation is determined by the angle through which a beam of polarized light is rotated when passed through a solution of a sample of sugar, the percentage of pure sugar being shown by a specially prepared table when the angle of rotation has been determined. For some years a difference has existed between the experts of the government and those employed by the sugar interests as to the effect of temperature upon the indications of the polariscope, and although the difference is only a fraction of one per cent., it amounts to a large sum when applied to the hundreds of millions of dollars paid in duty during the last few years. The question is being contested in the courts and in the meantime the bureau is making some careful investigations on the subject in the interest of the government.

Another line of the bureau's work not yet fully established is the testing of gas and water meters, pressure gauges and manometers for high and low pressures, engine indicators and the determination of the strengths of materials including cements and other building materials. This will probably develop into a very important branch of our work, in which we can be of much service to scientific and technical laboratories, as well as to the government and the public.

The official testing of scales, measures of length and volume, gas, water and electricity meters and other instruments by which the commodities purchased by the people are measured is not done in this country as thoroughly as it ought to be. In very few cities do the sealers of weights and measures go about systematically testing the instruments employed for measuring merchandise. England surpasses us in looking after the interests of the people in this particular. One of the functions of the bureau is to educate the public to the importance of this work. A step in this direction is the national convention of sealers of weights and measures to meet next month in Washington in response to a call issued by the bureau of standards.

The various lines of testing and research which have so far been mentioned, namely, weights and measures, heat and thermometry, light and optical instruments, and engineering instruments, are included in the first division of the work of the bureau of standards. The second division includes electricity and photometry. In the early days of its development electricity was essentially a qualitative science; its modern history has seen it become distinctly quantitative, and its wonderful development has been largely, if not mainly, due to the use of measuring instruments in studying and applying it. The three fundamental units of measure are the ohm, the unit of resistance; the ampere, the unit of current; and the volt, the unit of electromotive force. These are so related by Ohm's law that when two are defined the third becomes fixed and can be determined by the use of the other two. These units are not arbitrarily chosen, but are determined by experimental investigation. Their magnitudes depend upon the fundamental units of length, mass and time, and these having been selected (namely, the centimeter, gram and second), the definitions or specifications of the electrical units follow logically, but their concrete expression in actual standards that can be employed in electrical measurements can only be attained after most painstaking researches in what are called absolute measurements. The two of these three units which have been so determined are the ohm and the ampere. As all other electrical units are based upon these, it is of the greatest importance that they be determined with the utmost exactness. At the International Electrical Congress at Chicago, in 1893, they were redefined in accordance with the results of the best determinations made up to that time. The ohm is specified in terms of the resistance of a column of mercury 106.3 cm. long, having a cross-section of one square millimeter; the ampere in terms of the quantity of pure silver it will deposit electrolytically per second from a solution; the volt in terms of the electromotive force of the standard Clark cell. An immense amount of work has been done by numerous investigators in various countries of the world in the determination of the values of these electrical units, and the figures adopted in the definitions undoubtedly come very near the truth. Nevertheless, we know from subsequent work that at least two of these units are very slightly in error, and one of the most important problems before the bureau of standards is the redetermination of these fundamental units. The error in question is small, so small as to be of no consequence in engineering and commercial work. But scientifically it is important, and as instruments and methods are improved year by year, any small discrepancies in our fundamental units become of more and more significance. The National Physical Laboratory of England, the Physikalisch-Technische Reichsanstalt of Germany and the National Bureau of Standards, as well as a few private investigators in this country and abroad, are all working in the same direction. The recent International Electrical Congress at St. Louis provided for the formation of an international commission, whose function it shall be to foster and in some degree direct and coordinate researches of this character. This commission will probably organize and enter upon its work during the coming year. The difficulties to be overcome are so great that only the most elaborate researches carried out under the most favorable circumstances can be expected to bring us appreciably nearer the desired goal. Two researches at the bureau of standards during the past year gave results of value preparatory to the redetermination of the ampere in absolute measure. One was by Dr. Wolff, showing how to overcome one of the defects of the standard cell; a new method of preparing the mercurous sulphate yielding a crystalline product which gives cells of more uniform electromotive force than formerly. Professor Carhart, of Ann Arbor, who has been engaged upon this subject for some time, arrived independently at the same result even earlier, the results being announced by both men at the same meeting in Washington in April last. The other investigation was by Dr. Guthe, who, after carefully studying all the various forms of silver voltameters which have been proposed, showed that although different kinds gave slightly different results, certain ones when properly handled, gave practically identical results, and hence could be depended upon for measuring current to a very high order of accuracy. Dr. Wolff is continuing his work on standard cells and Dr. Guthe is now engaged in the absolute measurement of current, by means of a new electrodynamometer.

I have been engaged, with the assistance of Mr. Grover, Dr. Lloyd and several other members of the bureau, in the absolute measurement of electric capacity and inductance and in the investigation of electrical measuring instruments, more especially for the precise measurement of alternating current, voltage and energy. These investigations have involved the construction of much new apparatus, as well as the thorough study of some well-known instruments. One of the practical problems in connection with the accurate measurement of capacity or inductance is the determination of the frequency of the interrupter or of the alternating current employed. This usually amounts to obtaining the speed of some kind of motor, often an electric motor. For some kinds of work, to be within one per cent. is considered sufficiently accurate. For other cases one tenth of one per cent. is none too good. In still others one hundredth of one per cent. is deemed necessary. In this work we sought to get the frequency to a thousandth part of one per cent. This required a very perfect control of the speed, and yet by attention to all the sources of disturbances, and by the use of a very sensitive indicator, the desired result was obtained and an important additional step taken in absolute measurements.

Many other interesting and important questions are being investigated, and work enough for years is already before us. These particular examples of the work at the bureau have been cited, not because I presume that you are especially interested in the problems themselves, but rather to illustrate the kind of research work we are doing.

The work of testing is being carried on at the same time. Resistance standards, current standards, standard cells, wheatstone bridges, potentiometers, magnetic instruments, current instruments, voltmeters, wattmeters, condensers, inductances and many other electrical instruments have come to us from manufacturers, universities, technical laboratories and departments of the national government. To be able to get reliable standards and to have instruments calibrated at a nominal cost is a boon to all careful experimentalists. Heretofore it has often happened that the burden of the work in a given investigation has been to calibrate the instruments employed, and often the facilities at command were insufficient to yield results of high accuracy. Within the last three years (that is, since the bureau has been testing instruments) there has been a marked improvement in the quality of some kinds of electrical instruments made in this country. It is now so easy to determine whether a resistance box guaranteed by the maker to be correct to one fiftieth of one per cent. fulfils the guarantee, that the maker is compelled to use correct standards and to adjust his resistances carefully in accordance with the same.

Probably the most interesting collection at the St. Louis Exposition from the standpoint of physical science was the magnificent exhibit of scientific instruments made by Germany. There was a time not so very long ago when France and England surpassed Germany in the production of scientific instruments. But the giant strides which Germany has made in the last twenty years has left other countries in the rear, and this wonderful progress has been largely due to the wise encouragement and assistance offered to instrument makers by the German government. This assistance has taken various forms, but the principal factor has probably been the work of the Reichsanstalt and the Normal Aichungs Kommission, the two government laboratories doing the work which the bureau of standards aims to do in the United States. They have set a high standard for scientific instruments, and have not only shown how defects could be corrected, but have developed the theory and the design of many new instruments. All this has occurred so recently that it is not generally known in the United States, and German instruments are not as largely used as they deserve to be. We hope that the next few years may witness a similar impetus in the production of scientific instruments in this country, and that the United States may come to hold the same enviable position with respect to scientific instruments in general that she now does with respect to tools and labor-saving machinery and to certain special classes of scientific instruments.

The advantage of having instruments and standards of high accuracy for engineering and research work is obvious and needs no proof. I wish, however, to point out the advantage of using such instruments as far as practicable for purposes of instruction, especially in the more advanced laboratory courses. If the apparatus is not accurately adjusted the careful student and, perhaps, his instructor as well, is prone to lose valuable time in trying to locate errors that are inherent in the apparatus, or in striving for a degree of accuracy which is unattainable with the instruments employed. On the other hand, when the apparatus is known not to be correct it is so easy to attribute to the instruments any discrepancies in the results that careless reading and hasty work may possibly be encouraged. It is a great delight to the real lover of quantitative experimental work, of whom a great many are to be found in almost any college class, to do a piece of work with precision instruments and obtain an accurate result, duly checked by proper variations of the experiment. The educational value of such work is certainly greater than when only roughly done; the pleasure derived is incomparably greater. It is by no means necessary that all the instruments of a laboratory be sent away to be tested. If only the laboratory possesses correct standards and suitable comparing apparatus, the calibration or adjustment of most of the other instruments furnishes excellent experimental work for the students and assistants of the laboratory.

Another important section of the work of the bureau is photometry. This is really optical rather than electrical, but owing to the fact that the chief work is with electric lamps and a very considerable electrical equipment is required, it is grouped with the electrical in our organization. The standards employed in photometric testing are less satisfactory than in most other branches of physical measurements. The quantity of light emitted by a given source is usually expressed in candle power; the ordinary incandescent electric lamp, being approximately equivalent to sixteen standard candles, is called a sixteen candle-power lamp. The candle as a standard of measure has passed out of vogue, but light is still expressed in candle power. Various sources of light have been proposed as standards, the Hefner lamp burning amyl-acetate, being most used as a primary standard. As working standards specially prepared incandescent lamps are generally used, and are quite satisfactory. Greater progress has been made in recent years in developing photometers and the auxiliary apparatus for comparing lamps than in perfecting a primary standard of illumination. Although the initial equipment of the bureau for this work is not yet complete, we have already done considerable testing, especially in rating lamps to be used as standards by manufacturers and others, and in testing lamps purchased by the various departments of the government. Millions of incandescent lamps are sold each year on carefully drawn specifications, and it is a matter of considerable importance to know whether the conditions of the contracts are met by the manufacturers.

In addition to the exhibit made by the bureau of standards in the government building at the St. Louis exposition, an electrical laboratory was equipped and maintained in the electricity building. This was done at the request of the exposition management, the object being twofold; first to exhibit a working electrical laboratory, and, second, to do electrical testing for the jury of awards, for the railway test commission, and other electrical interests at the fair. The laboratory building, which was within the palace of electricity, and extended along one of its walls for a distance of about 175 feet, was divided into six rooms. Notwithstanding the fact that it was a temporary structure the laboratory possessed many of the appointments of a permanent installation; and, although many disadvantages and limitations were experienced in doing scientific work amid such surroundings, we succeeded in doing a good deal of satisfactory work, including both research and testing. So complete a laboratory has never been installed in any previous world's fair, and it proved to be of considerable interest both to visitors and to those electrical interests which availed themselves of its facilities for testing instruments. A refrigerating machine, installed adjacent to the laboratory as an exhibit, furnished refrigeration for experimental purposes and also for controlling the temperature and reducing the humidity of the atmosphere within the laboratory. This proved not only a great convenience in doing experimental work, but also a comfort to the workers, and the cool office of the bureau was a favorite retreat for the electrical jury in the hottest days of the jury period.

The third division of the work of the bureau is the chemical division, in charge of Professor W. A. Noyes. The development of this work has waited on the completion of our laboratory buildings. The installation of the equipment of the chemical laboratory is, however, now in progress and chemical work will be well under way before the end of the present fiscal year. The work in chemistry will consist in part in cooperating in certain lines of physical research, and in part in serving the chemical interests of the country. This will be done partly by research and partly by testing.

The bureau has already done considerable testing of apparatus used in volumetric analysis. The American Chemical Society, through its committee, has been cooperating with the bureau in fixing the limits of tolerance for such apparatus and in defining the specifications to be followed by the manufacturers. Another committee of the American Chemical Society has proposed a plan whereby standards of purity of chemical reagents shall be set, after careful investigation of the subject, and specific labels selected to indicate definite degrees of purity of such reagents. The bureau of standards, according to this plan, is to cooperate with the society in securing conformity to these standards on the part of manufacturers. I will not undertake to give details of the proposition; the work is of great importance and promises to bring the bureau of standards into close relations with the manufacturing and analytical chemists of the country. Another subject in which the bureau has been invited to cooperate with the American Chemical Society is in the matter of securing uniformity in technical analyses. Too great discrepancies are found in the results obtained by different public and other chemists when analyzing portions of the same sample. This is largely due to the different methods of analysis.

It is proposed to investigate thoroughly the various methods employed, and to select certain of the best as standard, with the expectation that, using the best reagents, the results found by different analyses may be more concordant and more accurate. Other lines of research and testing are contemplated, and will be undertaken as the facilities permit.

The field of chemistry, as well as physics, has so expanded in recent years that the two now overlap over large areas. Indeed, it is often impossible to say that a given problem belongs to one or the other, the fact being that, it pertains to both fields. Hence, the physicist frequently comes to the point where he needs the resources of a chemical laboratory to carry him through a problem supposed to be purely physical, and conversely the chemist, not only in electro-chemistry and physical chemistry, but in analytical chemistry as well, requires very many of the facilities of a well-equipped physical laboratory. Hence we have so planned our laboratories that all the facilities of the entire equipment may be brought into service on any problem, whether it originates on the physical side or on the chemical. This we believe will prove of great advantage to the work of the bureau.

There are three chemists in the chemical division at present and the number will be increased as the work develops.

It is the aim of the bureau not only to conduct investigations through its members, but also to afford facilities for research by others who may come as scientific guests. It often happens that a proposed investigation requires apparatus or other facilities not at the command of the person proposing the investigation, and no university can, perhaps, offer him the necessary facilities and assistance. The bureau of standards hopes to encourage investigation by providing such facilities and assistance, but can do so only to a limited degree until the laboratory space is increased by additional buildings. There are scores and perhaps hundreds of ambitious physicists, young and old, engaged in teaching in the colleges and technical schools of the country who are deterred from doing valuable research work by lack of facilities and assistance. It is believed that a generous policy of assistance through the bureau of standards will be greatly appreciated by such workers, and that the output of original research from America will be materially increased thereby. A summer's work under favorable circumstances might yield as much as a full year's effort under adverse conditions, and a year, enough to amply repay the sacrifice it might involve. But, as I have already said, the full realization of this plan lies in the future. For the present all our laboratory space is required to meet our own pressing needs, although we do have just now one scientific guest with us, about to begin some interesting investigations.

I have tried to show briefly some of the work which the bureau of standards is doing and is preparing to do, to fulfill its functions as the American National Physical Laboratory, using the word physical in a liberal sense, as its work includes both chemistry and engineering. The national government is doing a large amount of scientific work, through the various bureaus and departments. That money expended in this direction is well invested, the Department of Agriculture, the Coast and Geodetic Survey, the Geological Survey and other bureaus have already abundantly proved. Their function and ours is to contribute something to the advancement of human knowledge and to serve the public. We hope not only to be of service to scientific and technical laboratories in the various ways I have tried to explain, but also to serve in many ways the larger general public.

It is a peculiar pleasure to me to be present to-day at the dedication of the John Bell Scott Physical Laboratory. It is a beautiful building, a fit representative of the splendid science to which it is dedicated; a notable addition to the equipment of Wesleyan, testifying eloquently to the generosity and loyalty of the donors; a worthy memorial to the unselfish life of the noble young man after whom it is named. The good it will do in the future years is immeasurable.

Edward B. Rosa.
National Bureau of Standards.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. SECTION A, MATHEMATICS AND ASTRONOMY.

Vice-President—Professor Alexander Ziwet, University of Michigan, Ann Arbor, Michigan.

Secretary—Professor Laenas G. Weld, University of Iowa, Iowa City, Iowa.

Member of the Council—Professor J. R. Eastman.

Sectional Committee—Superintendent O. H. Tittmann, Vice-President, 1904; Professor Alexander Ziwet, Vice-President, 1905; Professor L. G. Weld, Secretary, 1904–1908; Dr. J. A. Brashear, one year; Professor J. R. Eastman, two years; Professor Ormond Stone, three years; Professor E. B. Frost, four years; Professor E. O. Lovett, five years.

Member of the General Committee—Professor G. B. Halsted.

Press Secretary—Professor J. F. Hayford.

Dr. W. S. Eichelberger, of the U. S. Naval Observatory, was elected vice-president for the next meeting.

The Astronomical and Astrophysical Society of America met in affiliation with Section A, the two organizations holding alternate sessions on December 28, 29 and 30.

The vice-presidential program was presented on the afternoon of Wednesday, December 28. In accordance with the recommendations of the Committee on the Policy of the Association this program was given a broader scope than heretofore and included the address of the retiring vice-president, Superintendent O. H. Tittmann, upon the subject 'The Present State of Geodesy,' and a paper by Professor Josiah Royce, of Harvard University, entitled 'Symmetrical and Unsymmetrical Relations in the Exact Sciences.' The former of these has been published in Science for January 13, and the latter will appear in an early number of the same journal.

The following papers were presented at the regular meetings of the section:

Synchronous Variations in Solar and Meteorological Phenomena: Mr. H. W. Clough, U. S. Weather Bureau, Washington, D. C.

The portion of the paper relating to meteorological phenomena is essentially an extension of Professor Brückner's researches on the 35-year cycle of variation in terrestrial climates. Definite epochs have been assigned for the variations of the several meteorological elements and the results of Brückner have been supplemented by investigations of various minor meteorological relations and the prices of grain. The probable value of the period length is found to be 36.2 years, instead of 34.8 years, Brückner having used in calculating the latter value an extra oscillation in the sixteenth century, which should be regarded as a secondary variation. Brückner traced the cycle as far back as 1000 A. D. by means of historical accounts of several winters. Comparison of the epochs in different latitudes discloses an apparent retardation in low latitudes. This may indicate that the influence efficient in producing these variations is experienced mainly in high latitudes. Periods of excessive precipitation follow by about five years those of deficient tem-