A paper presented at the 146th Meeting of the American Institute of Electrical Engineers, New York, September 26, 1900. President Hering in the Chair.

THE IMPERIAL PHYSICO-TECHNICAL INSTITUTION IN CHARLOTTENBURG.

BY HENRY S. CARHART.

I. Historical.

Through the courtesy of Professor Kohlrausch, President of the Reichsanstalt, and the Curatorium or governing body of the institution, the writer was accorded the privilege of working in the Physikalisch-Technische Reichsanstalt as a scientific guest during the last few months of 1899. An unusual opportunity was thus afforded of learning rather intimately the methods employed and the results accomplished in this famous institution for the conduct of physical research, the supply of standards, and the verification of instruments of precision for scientific and technical purposes.

It is well-known that the Reichsanstalt is situated in Charlottenburg, a suburb of Berlin just beyond the renowned Thiergarten. The buildings occupy an entire square, the larger part of which, valued at 500,000 marks, was the gift of Dr. Werner Siemens. In making this gift, which was offered in land or money at the option of the government, Dr. Siemens declared that he had in mind only the object of serving his fatherland and of demonstrating his love for science, to which he avowed himself entirely indebted for his rise in life. The gift was made as a stimulus to the government to establish an institution for physical research. The kind of institution desired had been amply described in suitable memorials prepared by himself, Professor von

Helmholtz and others of scarcely less distinction. The first memorial bears date of June 16, 1883. It relates to "The Founding of an Institution for the Experimental Promotion of Exact Natural Philosophy, and the Technical Arts of Precision." It points out the need of such an institution, details the benefits likely to accrue from it, lays great stress on the intimate relation existing between scientific investigations and their application in the useful arts, and sets forth somewhat in detail a plan of organization. The memorialists had in mind at that time a "Physico-Mechanical Institution," but in a memorial of the following year (March 20, 1884) the title was changed to the one which the institution now bears—"Physikalisch-Technische Reichsanstalt." From this second memorial it is learned that the first steps toward the furtherance of exact science and technical precision in an institution to be founded and maintained by the State, were taken as early as 1872. This movement had the support of the crown prince, the late Emperor Frederick, and the matter was taken in hand by Count von Moltke as chairman of the Central Bureau for Metrology in Prussia. He called together a commission near the end of the year 1873, and in the following January this commission reported a series of propositions for the improvement of the scientific mechanic arts, and of instruments of precision. These propositions formed the foundation for a memorial on the same subject to the Chamber of Delegates of the Prussian Government in 1876. The result was that appropriate rooms were set aside in the new building of the Technical High School in Charlottenburg for the organization of an institution for the cultivation of the arts of precision.

The general plan of the Reichsanstalt was adopted in 1887, and an appropriation of 868,254 marks was made and spread over the budget for three years. The main building for the first or scientific division was completed in 1893. The second or technical division was housed in a portion of the Technical High School till the buildings for this division were completed in 1897. All departments of activity of the Reichsanstalt are now accommodated on the square facing on March Strasse in Charlottenburg. They include the division for pure scientific research, mechanical measurements of precision, electrical measurements and instruments, the measurement of large direct and alternating currents and electromotive forces, the optical department, the department of thermometry, the department of pyrometry, and the depart-

ment of chemistry. To these as auxiliaries should be added the power plant and the workshop.

II. Organization.

The two divisions into which the Reichsanstalt is divided correspond to the two paramount objects which the founders had in view, viz., research in pure science, and the cultivation of precision in the technical applications of science. The same idea is embodied in the very name of the institution—The Imperial Physico-Technical Institution. If the sole purpose of the Anstalt had been the promotion of improvements in the mechanic arts, in engineering, and in instruments of precision, the first or scientific division would still have been essential to secure the ends sought. All the applications of science rest on the foundation of pure scientific discovery. The creation of new and improved methods and instruments for physical measurements requires the most exhaustive and painstaking investigations as a preliminary to a steady and confident advance. The practical value of research in pure science is no longer in question. The wise founders of the Reichsanstalt made no mistake in coupling an institution for the promotion of technical precision with one for the prosecution of research in physical science.

The governing body or Curatorium of the Reichsanstalt is appointed by the Emperor. At its head is Herr Weymann, Imperial Privy Counsellor. The function of the Curatorium is the appointment of the officials and the general management of the institution. The chief officer of the Reichsanstalt is the President, and the most distinguished physicist of the realm is sought for this position. Helmholtz was taken from the University in Berlin to become the first incumbent of the office; after his death in 1894, his successor as professor of physics in the University, Professor F. Kohlrausch, became his successor as President of the Reichsanstalt.

The President, who is at the same time director of the first division, is held responsible for the successful work of the Reichsanstalt. All other officials are therefore subordinate to him. In his absence the duties of his office devolve upon the Director of the technical division. Subordinate to the Director of this second division are the professors, associates, and assistants of various grades. A professor in charge of a department has the direction of all those employed in it, including a skilled departmental mechanician.

The specific duties of the President may be briefly enumerated. He must lay before the Curatorium at its annual meeting the following:

1. A report on the work executed in both divisions.
2. The plan of work for the undertakings to be carried out the ensuing year.
3. Propositions relative to the money to be expended for scientific and technical work; also for salaries and remunerations.
4. Propositions relative to the rank of permanent associates

FIG. 1.—President's House.

and assistants; also relative to the bestowal of places to work in the Reichsanstalt as scientific guests.

He takes a vote on the propositions in 3 and 4, and reports the conclusions of the Curatorium to the government for approval. It is also the duty of the President to sign vouchers for all payments, and he is held responsible for the proper expenditure of the money appropriated for the maintenance of the institution.

The different functions of the two divisions composing the institution are defined in rather broad terms. It is the duty of the first division to carry out physical investigations requiring more

uninterrupted time on the part of the observer, and better accessories in the way of instruments and local appliances, than private individuals and laboratories of institutions for teaching as a rule can offer. These investigations shall be carried out partly by officers of the Anstalt and partly, under their oversight, by scientific guests and voluntary workers. By scientific guests in general are meant the holders of scientific positions in the German empire, who wish to prosecute scientific researches, the plan of which they have submitted, and for which they have not at home

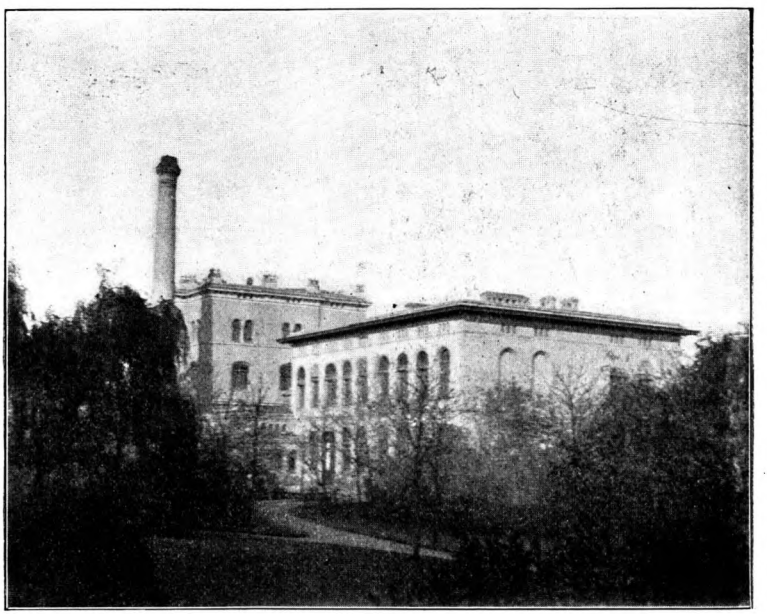

FIG. 2.—Building for Large Current and Machinery.

the necessary appliances. They must be recommended by the State in which they reside and must be accepted by the Curatorium.

Young men may be accepted as voluntary workers who have proved their ability by scientific publications. They will undertake researches which have been determined upon by the Curatorium or the Director; or they may investigate subjects which they themselves suggest, and which appear to the Director to be practicable and worthy of execution. The scientific results obtained must be published only at the discretion of the authorities

of the institution, who reserve also the right to publish them in the researches of the Reichsanstalt. Provision is made that voluntary workers shall not use the institution for private ends nor to obtain patents.

The second division of the Reichsanstalt is placed under a Director, who is subject to the higher authority of the President. Such a Director was considered necessary on account of the special work of this division, as well as because of the intimate relations into which it is brought with many persons engaged in

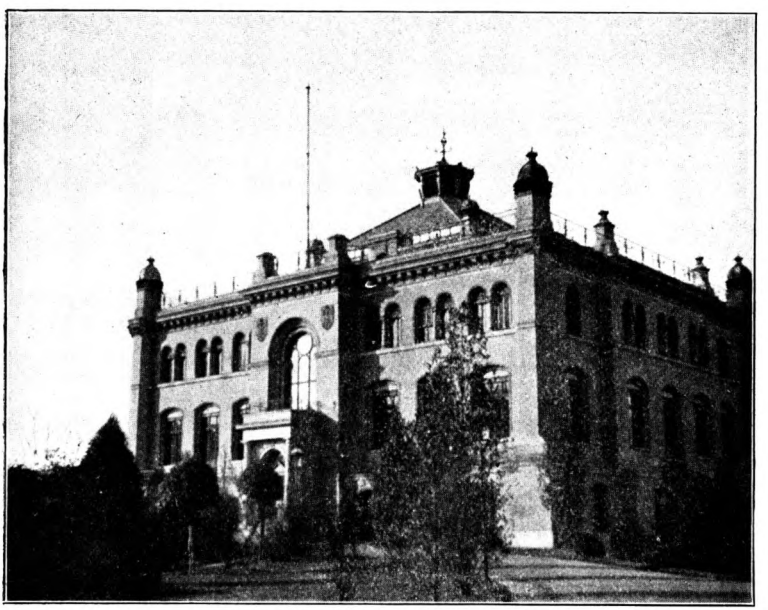

FIG. 3.—Main Building, Division I.

industrial pursuits. He should therefore not only be a scientific man but should at the same time have some technical knowledge of the applications of science. Under the Director are placed the permanent heads of the subdivisions of the technical department, one having the oversight of thermometry, one of optics, two of electricity, and one of mechanical measurements of precision. Along with these and of the same rank and compensation is the director of the workshop. Under him at present are eight mechanics, and the shop is provided with the finest tools for the execution of the most exact work required by the institution. For

example, it has a circular dividing engine that cost $2,500. The founders of the Reichsanstalt foresaw the necessity of such mechanical aids for the furtherance of the exact work to be undertaken. They wisely concluded that such special constructions and new types of instruments as they might require from time to time could be more conveniently and more cheaply built in their own shop than by private instrument makers.

III. Cost and Maintenance.

The following are the official accounts of expenditures for the

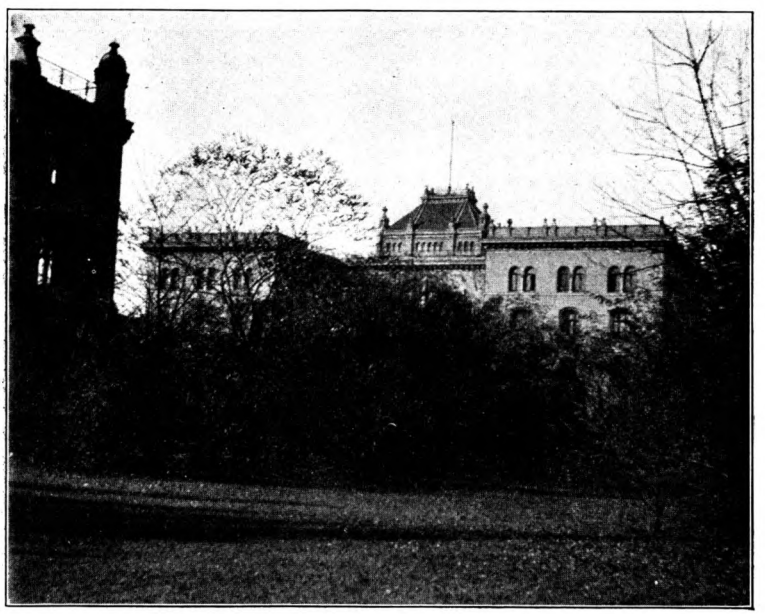

Fig. 4.—Main Building, Division II.

grounds, buildings, furniture and instruments for the two divisions, to which are added the yearly expenses:

Division I.

1.	Acquisition of ground, the gift of Dr. Werner Siemens	500,000 M.
2.	For erection of buildings:	
	a. Main Building	387,000 "
	b. Machinery Building	50,000 "
	c. Administration Building	100,000 "
	d. President's House	99,254 "
	e. Grading, Paving, etc.	10,472 "

	f. Paving Half of Street	30,274 "	
	g. Building for Battery	8,500 "	
3.	Fittings and Furniture	58,000 "	
4.	Equipment of Machinery and Instruments	82,310 "	1,325,810 M.

DIVISION II.

1.	Acquisition of Ground	373,106 M.	
2.	Erection of Buildings :		
	a. Main Building	922,000 "	
	b. Laboratory Building	218,000 "	
	c. Machinery "	180,000 "	

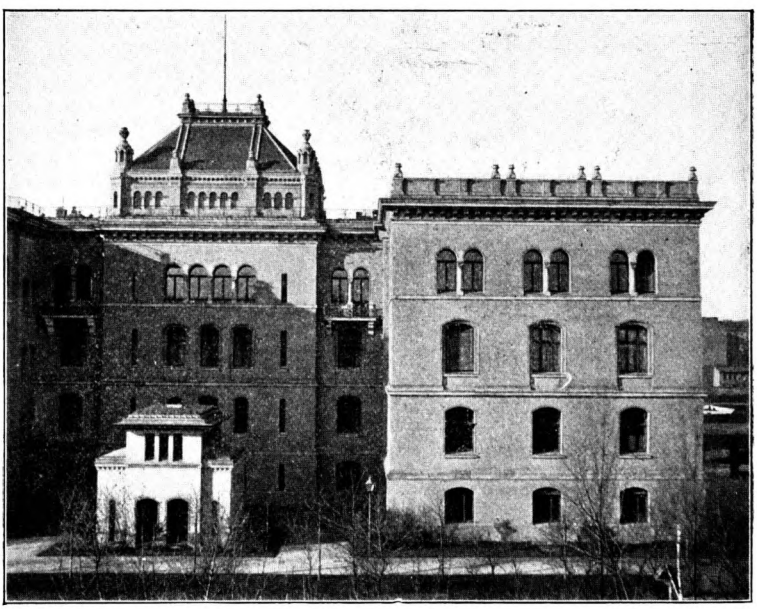

FIG. 5.—Main Building. (In part.)

	e. Dwelling for Officials	140,000 "	
	f. Additional Improvements	348,000 "	
3.	Fittings and Furniture	108,300 "	
4.	Equipment of Machinery and Instruments	471,390 "	
		2,760,796 "	
	Less reduction for 1895–96	47,500 "	2,713,296 M.
	Divisions I and II together		4,039,106 "

The annual expenditures for 1889 were as follows :

1.	Expenditures for Salaries and Laborers	206,604 M.
2.	Miscellaneous Articles, Experimental Work and care of Buildings	127,000 "
	Total	333,604 "

The receipts for calibrating instruments, testing materials, verifying standards and the like now amount to about 40,000 M. annually. This sum should be deducted from the yearly expenditures, leaving a net sum of about 300,000 M.

In round numbers the Reichsanstalt has cost $1,000,000, and the annual appropriation for its maintenance is $75,000.

IV. Results.

A very pertinent inquiry is, what are the results of all this expenditure? Might not more good be accomplished by state aid to some existing technical school or university? The results attained must be set by the side of the objects which the founders of the institution had in view in order to ascertain whether the sequel has justified their predictions. In the memorials to which reference has already been made, Professor von Helmholtz and Dr. Werner Siemens pointed out the advantages likely to accrue to Germany from the maintenance of an imperial institution for research, which should at the same time assume the cognate function of fixing and certifying standards of mechanical and physical measurements. Attention was drawn to the fact that other countries, notably England, had enjoyed great renown in science because of the brilliant researches and discoveries of some of her scientific men, who had the good fortune to be possessed of leisure and large private means, and the scientific spirit to devote them to investigations demanding both as a *sine qua non*.

These conditions the memorialists declared were lacking in the fatherland. Her scholars who had the enthusiasm and the capacity for exact scientific investigation possessed neither the private fortune to devote to it, nor the uninterrupted time for the execution of the work. They were to be found among the men engaged in teaching, but their professional duties absorbed their time to such an extent that only an inadequate residue remained; and even that little was divided into fractions too small to admit of the sustained and continuous attention which any important investigation demands.

It was further pointed out that if the government would supply the conditions favorable to scientific discovery, the men could be

found whose work would reflect great credit on the state, while the interaction between pure science and its applications to arts and manufactures would put Germany in the forefront of scientific renown and of the intelligent application of science to useful purposes.

It was further urged by von Helmholtz that the brilliant investigations of Regnault and other French physicists many years ago should now be repeated with the superior methods and instrumental appliances available at the present time. These investigations drew the attention of the scientific world to France and made it the focus of scientific interest. Her instrument makers, even up to the present, have reaped a rich reward in foreign orders for instruments made eminently desirable and almost indispensable by these distinguished French investigators.

Other problems, too, needed solution, problems forced to the front by modern requirements and discoveries. The applications of electricity, for example, present new questions for science to answer, while the interests of the consumer at the same time call for some form of control by the State of the instruments employed in fulfilling contracts. The very units in which such measurements are made need to be authoratively settled—a task demanding the highest manipulative skill in experiment and the most refined appliances which experience can suggest and money purchase.

The German government admitted the force of these considerations and made splendid provision, both for pure science and its technical applications, by founding the Imperial Institution at Charlottenburg. The results have already justified in a remarkable manner all the expenditure of labor and money. The renown in exact scientific measurements formerly possessed by France and England has now been largely transferred to Germany. Formerly scientific workers in the United States looked to England for exact standards, especially in the department of electricity. Now they go to Germany. So completely has the work of the Reichsanstalt justified the expectations of its founders, and so substantial are the products of this already famous institution that other European nations are following Germany's example. Great Britain has already made an initial appropriation for a National Physical Laboratory to be organized on a plan similar to that of her Teutonic neighbor. Mr. R. T. Glazebrook, who has long served as Secretary of the Electrical Standards Com-

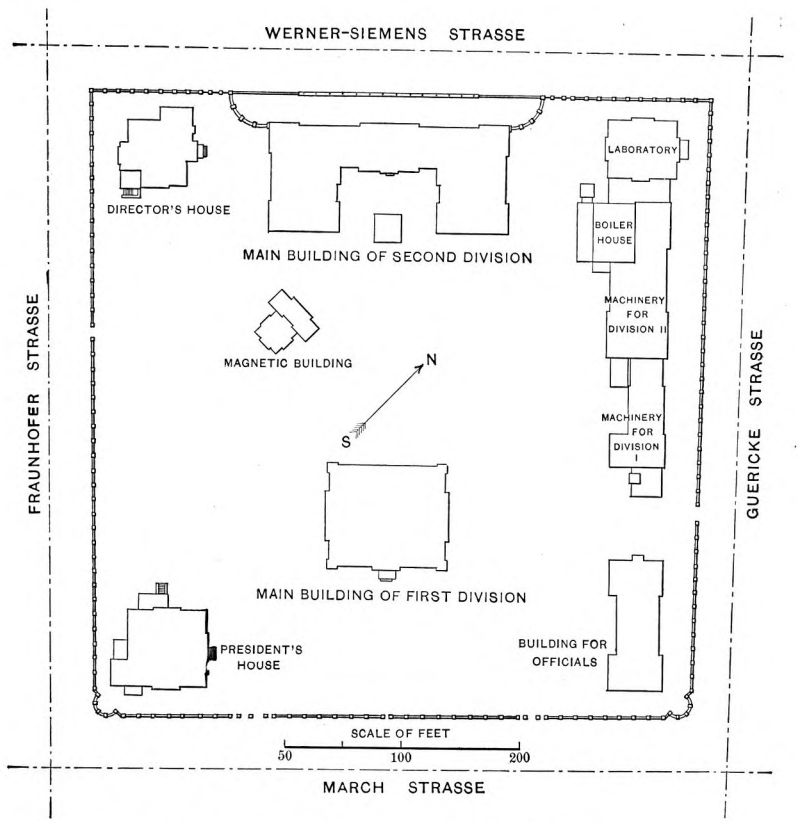

FIG. 6.—General Plan of Ground and Buildings.

mittee of the British Association for the Advancement of Science, has been appointed Director and has entered on his duties. The new institution will absorb the old Kew Observatory, and other buildings will be added at once for the extension of the functions of this Observatory so as to include the larger enterprise contemplated in the establishment of the new National Laboratory.

Russia also has a number of large and well equipped laboratories in connection with her Central Bureau of Weights and Measures. One of these is devoted to the verification of instruments for electrical measurement. It employs fourteen men and the budget is about $45,000 per annum.

France is also moving in the same direction. The great service of France in fixing standards of length and mass has long been freely recognized by the civilized world. But her national bureau for this purpose is now considered to be too limited in scope to solve the new problems presented. Quite recently a committee of learned men from Paris, under the leadership of Minister Bourgeois, visited Charlottenburg for the purpose of examining into the working of the renowned institution located there. Professor Violle, one of the most illustrious physicists of the French capital, accompanied the committee. What better evidence of the success of Germany's great institution can be demanded than the consensus of favorable opinion among those best qualified to judge that its fruits are already of the highest order of merit, and its imitation by other European nations—the sincerest form of flattery.

It would not be just to form an estimate of the success of the Reichsanstalt without taking into account its scientific publications. These are numerous and of great value. Most of the reports of work done are made public with official sanction in various scientific and technical journals. During the past year thirty such papers have been published. The detailed accounts, however, of the most important undertakings thus far completed are contained in three quarto volumes of investigations. Among those contained in the first two volumes may be mentioned papers pertaining to thermometry and to units of electrical resistance.

The investigations in thermometry comprise such topics as the influence of the glass on the indications of the mercurial thermometer, division of the thermometer and determination of the errors of division, determination of the coefficient of outer and

inner pressure, determination of the mean apparent coefficient of expansion of mercury between 0°C. and 100°C. in Jena glass, and investigations relating to the comparison of mercurial thermometers.

Four papers of exceptional value relate to normal standards of electrical resistance. They are, the probable value of the ohm according to measurements made up to the present time, the determination of the caliber correction for electrical resistance tubes, the normal mercury standard ohm, and the normal wire standard ohm of the Reichsanstalt. When one recalls that the ohm as a practical unit of measurement is defined in terms of the resistance of a specified column or thread of mercury, it will readily be seen that the work done at Charlottenburg in this particular field is fundamental in character and of the most universal importance.

In passing it is worthy of remark that all the standard resistances designed and constructed at the Reichsanstalt are carefully compared with the mercurial standards early in each year. This custom is in accordance with the action taken by the electrical standards committee of the British Association at Edinburgh in 1892, when the mercurial standard was definitely adopted. At this meeting of the committee, representatives of American, French and German physicists (including von Helmholtz) were invited to sit as members. The methods employed in these comparisons and the forms of the standards are original with the Reichsanstalt. The new forms and methods admit of a combined accuracy and convenience not previously attained.

In addition to the work done in electrical resistance, the investigation of the silver voltameter and the electromotive force of standard Clark and Weston cells has been highly productive of useful results for the other two fundamental electrical measurements. Much remains to be done in this latter direction, for the electromotive force assigned to the Clark and the Weston cell, even in the latest report of the Reichsanstalt, is derived from measurements by the silver voltameter, while the electrochemical equivalent of silver is in doubt to a greater extent than the electromotive force of the Clark cell.

Perhaps the best indication of the valuable work of the Reichsanstalt is to be found in the annual "Thätigkeitsbericht." This report of the year's activity is published in the "Zeitschrift für Instrumentenkunde," and the reprint for 1899 forms a pamphlet

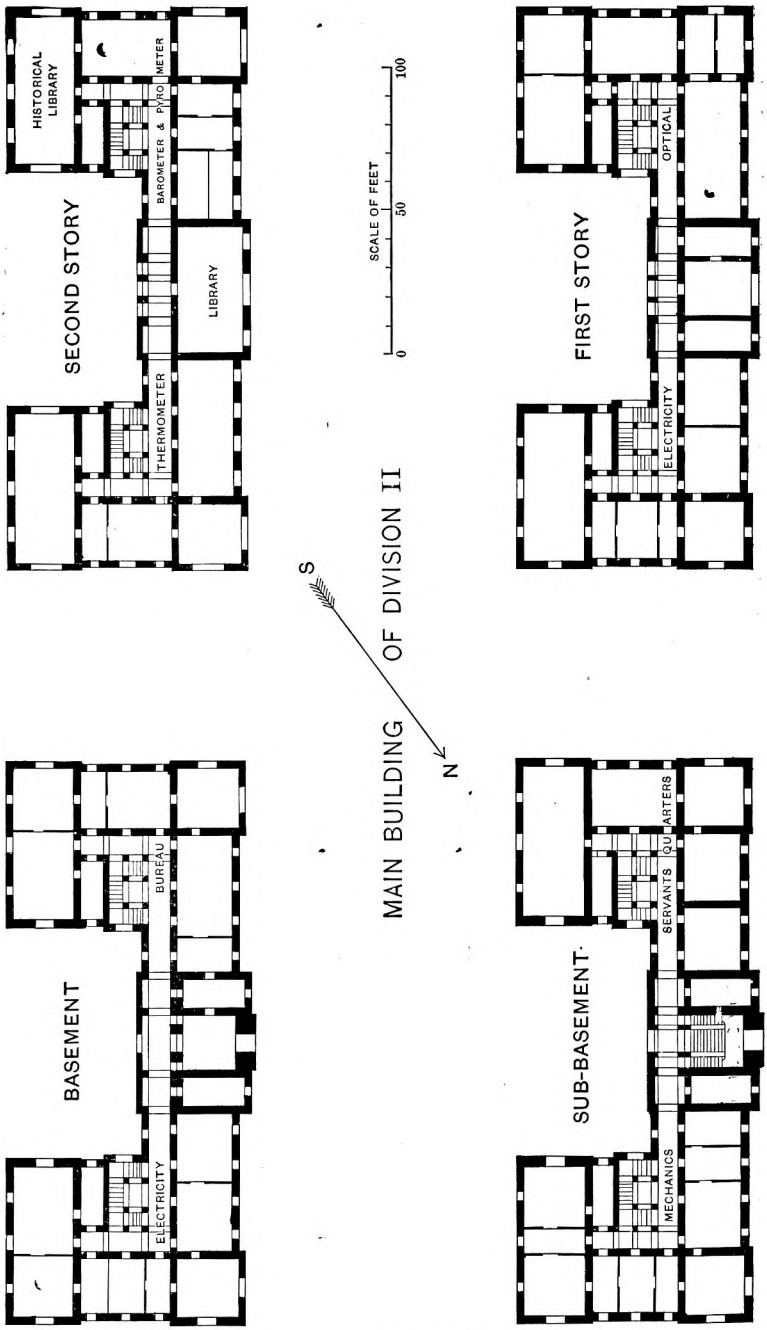

FIG. 7.—Floor Plans of Main Building. Division II.

of twenty-five large, closely printed pages. The following abstract will convey some impression, though an imperfect one, of the extent of the work accomplished:

FIRST (PHYSICAL) DIVISION.

I. *Work in Heat.* Determination of the density of water between 0°C. and 40° C.

Determination of the pressure of water vapor at low temperatures.

Determination of the pressure of water vapor near 50° C.

Investigation of thermometers for temperatures between 100° and 200° C.

Investigation of the nitrogen thermometer with a platinum-iridium bulb for very high temperatures.

Investigation of thermometers for low temperatures.

Determination of the thermal and electrical conductivity of pure metals. (These determinations are to be extended down to the temperature of liquid air and up to 1000° C.)

Investigations with the Fizeau-Abbe dilatometer.

Investigation of the transmission of heat through metal plates.

II. *Work in Electricity.* Comparison of the normal wire resistances of Divisions I and II.

Determination of the capacity of an air condenser.

Comparison of the standard cells of Divisions I and II.

Determination of the conductance of water solutions with a higher degree of accuracy than has been attained hitherto, especially with very dilute solutions.

III. *Work in Light.* Investigation with electrically heated black bodies.

Proof of Stefan's law between 90° and 1700° absolute temperature.

Determination of the relation between the intensity of light and the temperature.

Measurement of radiation in absolute measure.

Determination of the distribution of energy in the spectrum of black bodies.

Determination of the distribution of energy in the spectrum of polished platinum and other substances; also their reflective power.

SECOND (TECHNICAL) DIVISION.

I. *Work of Mechanical Precision.* Investigation of the errors of length and of the division of 300 scales, tubes, etc.

Coefficient of expansion of 18 bars, tubes and wires.

Verification of 86 tuning forks for international pitch.

Construction of a new transverse comparator.

Study of the variations of angular velocity of rotating bodies.

II. *Electrical Work.* Calibration of direct current apparatus, 183 pieces.

Calibration of alternating current apparatus, 58 pieces.

Examination of other electrical apparatus, 76 articles.

Examination of accumulators, primary elements and switches, 37 articles.

Examination of insulating and conducting materials and carbons, 23 articles.

Installation of storage cells for a current of 10,000 amperes.

Installation of small storage cells for an electric pressure of 20,000 volts.

Installation of alternating current instruments for measuring potential difference up to 500 volts and current up to 100 amperes.

Examination of 29 samples of alloys for specific resistance and temperature coefficient.

Examination of 126 samples of insulating materials with an electric pressure up to 800 volts.

Verification of single resistances, 123 samples.

Calibration of 33 resistance boxes, compensation apparatus, etc., containing 1153 single resistances.

Comparison and verification of 133 standard cells—111 Clark and 22 Weston elements.

Determination of the ratio Clark 15° C. to cadmium 20° C., and Clark 0° C. to cadmium 20° C. with a large number of standard cells.

Examination of 21 samples of dry and storage cells.

Calibration of 15 galvanometers to measure high and low temperatures with thermal elements.

Magnetic examination of 25 samples of iron and steel.

Investigation of the difference between the continuous and the discontinuous magnetization of steel.

Investigation of the influence of repeated heating on the magnetic hardness of iron.

III. *Work Relating to Heat and Measurement of Pressure.* Calibration of 18,777 thermometers.

Examination of 4 safety appliances and benzine lamps.

Calibration of 317 thermal elements.

Verification of 9 manometers and 22 barometers.

Testing of 190 samples of apparatus for petroleum investigations.

Testing of 3210 samples of safety rings and plugs.

Testing of 22 samples of indicator springs.

IV. *Work in Light.* Testing of 149 Hefner lamps for photometric purposes.

Testing of 189 incandescent lamps.

Testing of 143 gas and other lamps and adjunct appliances.

Investigation of the relation between the temperature of sugar solutions and their rotatory power on polarized light.

Investigation of quartz plates for the examination of sugars.

Determination of 100 points in the normal Ventzke scale for sodium light.

Especially careful collection of sugars from Germany, Austria, France, Russia and North America for the investigation of specific rotatory power.

V. *Work in Chemistry.* Continuation of the study of the solubility of important salts.

Electrolysis of platinic chloride and the migration of the ions.

The quantitative determination of metallic platinum.

Investigation of liquids for use in thermometers to measure low temperatures.

In addition to the above work attention is drawn to the fact that there are two institutions for calibration and certification of thermometers under the control of the Reichsanstalt, one at Ilmenau and the other at Gehlberg. During the last ten years the institution at Ilmenau has tested in round numbers 350,000 thermometers.

The number of persons employed in the Reichsanstalt the past year was 87.

V. A Lesson for Us.

If Germany has found it to her scientific and industrial advantage to maintain the Reichsanstalt, and is proud of what it accomplishes; and if Great Britain is so impressed with the success of the institution that she has decided to imitate it, it is surely the part of wisdom for the United States to move in the same direction. It is therefore very gratifying that at the suggestion of Secretary Gage a bill was introduced in the last Congress to establish a National Standardizing Bureau, and that the Committee on Coinage, Weights and Measures reported unanimously and strongly in favor of its passage. So great is the importance of this movement from the point of view of science, of national pride, and of the higher interests of industrial pursuits, that the effort so happily begun, to secure suitable legislation should be repeated with redoubled force and enthusiasm. Some of the reasons for making this effort one does not need to go far to seek.

In the first place the scientific interests to be served are certainly as great as in any other country in the world. Science is cultivated here with increasing assiduity and success. We are no longer content to follow in the footsteps of European savants and modestly repeat their investigations. Original work of a high order is now done in many American universities; but the difficulties under which university instructors prosecute research are even greater here than in Germany, and we are still compelled to go to Europe for most of our standards. As a result, inventions of an almost purely scientific character originating here have been carried to perfection in the Reichsanstalt, and Germany gets the larger part of the credit. I need only instance the Weston standard cell, which has been so fully investigated at the Reichsanstalt, and the alloy "manganin," which the same institution employs for its standard resistances after a searching inquiry into its properties. Both of these are the invention of Mr. Edward Weston, one of the Past-Presidents of this Institute. So long as there is no authoritative bureau in the United States under Federal control, and presided over by men commanding respect and confidence, we must continue "to utilize the far superior standardizing facilities of other governments." It is true that science knows no nationality, but the scientific workers of any nation can serve their own country better if they are not compelled to obtain their standards and their best instruments from distant parts of the globe. America has the cultivation in

physical science, the ability on the part of her investigators, and the inventive faculty to do work in a national institution that we shall not be ashamed to place by the side of Germany's best products. The establishment of a national institution for physical and technical purposes can not fail to foster a vigorous and healthy growth in science, to which we already owe so much of our national prosperity and renown.

In the second place Congress should be stimulated to take action because of national pride. It is not creditable for a capable and self-reliant nation to continue to depend on foreign countries for its standards of measurement, for the certification of its instruments, and for the calibration of its normal apparatus for precise work. Different departments of our Government and offices under its control must at present appeal to foreign bureaus for the certification of their standards and instruments of precision. The first day the writer spent at the Reichsanstalt he was consulted with reference to an extended correspondence between the Director of the technical division and the officials of the Brooklyn Navy Yard relative to the calibration of a large number of incandescent electric lamps for use in our Navy department. The spectacle of a Government bureau going to a foreign imperial institution for standards in an industry whose home is in the United States is a humiliating one. Yet the proceeding was entirely proper and justifiable because there is in this country no standardizing bureau for the purpose desired. Are the representatives of the American people willing to have this state of affairs continue?

Again, the higher interests of the industrial utilization of scientific knowledge require the establishment in Washington of an institution similar to the Reichsanstalt and in no degree inferior to it. We are an inventive people and may justly claim renown in the prompt and efficient utilization of the discoveries in physical science. It is highly improbable that a practical limit has already been reached in the field of applied physics. We are not estopped from making further discoveries. Still it may be affirmed with confidence that the most important and promising work to be done, except in the rare instances in which genius makes a brilliant discovery, will consist in the more perfect adaptation of known physical laws to the production of useful results. It is precisely this field which has not been extensively cultivated as yet in the United States. We have explored the surface and presumably gathered the largest nuggets and the

most brilliant gems. To increase the output we must now delve deeper and scrutinize more closely. To drop the metaphor, what will be required for future preeminence is the more intensive and exhaustive study of the scientific conditions in the industrial utilization of physical laws. This study will require the best talent of our technical schools, aided and supported by an authoritative national institution, itself far removed from patents and commercial gains, but jealous of our national renown and eager to cooperate with manufacturers for the sake of national prosperity.

Germany is rapidly moving toward industrial supremacy in Europe. One of the most potent factors in this notable advance is the perfected alliance between science and commerce existing in Germany. Science has come to be regarded there as a commercial factor. If England is losing her supremacy in manufactures and in commerce, as many claim, it is because of English conservatism and the failure to utilize to the fullest extent the lessons taught by science; while Germany, once the country of dreamers and theorists, has now become eminently practical. Science there no longer seeks court and cloister, but is in open alliance with commerce and industry. This is substantially the view taken by Sir Charles Oppenheimer, British Consul-General at Frankfurt, in a recent review of the status and prospects of the German Empire.

The Reichsanstalt is the top stone of Germany's scientific edifice. It has also contributed much to her industrial renown. It is necessary to cite only her manufactures involving high temperatures, such as the porcelain industry, to appreciate the help afforded by the Reichsanstalt. The methods and instruments elaborated there for the exact measurement of high temperatures constitute a splendid contribution toward industrial supremacy in those lines. The German government sees with great clearness that the Reichsanstalt justifies the expenditure made for its maintenance, not by the fees received for certifications and calibrations, but by the support it gives to the higher industries requiring the application of the greatest intelligence. In this connection it should be thankfully acknowledged that the services of this imperial establishment are placed at the disposal of foreign institutions of learning with the most generous liberality. The charges for calibration are only about one-fourth the expense incurred in making them, but the support thus given to German makers of instruments of precision, by increasing their foreign orders, is deemed a sufficient return for the services rendered.

Discussion.

The President:—The subject is now open for discussion. It is unfortunate that Prof. Carhart is not present to answer questions, but it would nevertheless be interesting to hear the views of the members present on the subject of the paper. I had the pleasure of visiting this Reichanstalt only about a week ago, and if I can answer any questions I will be glad to do so; my visit was only a very short and hurried one.

I am very glad that Prof. Carhart presented this paper to the Institute, and that he brought out so forcibly in the last section, the need of a similar one in this country. It is certainly humiliating for us in this country to have to go to a foreign institution to have our instruments standardized. There is no reason at all why we should not do exactly the same kind of work here. The expense of conducting this creditable institution, seems to me to be exceedingly small. It is also somewhat humiliating for us that the Weston standard cell, which was invented here, was not appreciated by the world until after it had been investigated by the Reichsanstalt. The same is true of manganine, which now seems to be the standard resistance material in the Reichsanstalt; it seems, in fact, that the manganine standard resistances in that institution are depended upon more than the mercury ohms.

The Reichsanstalt, as Professor Carhart has described to us, is divided into two quite distinct departments, the one for research and the other for what might be called commercial standardization. Prof. Carhart in his paper puts more stress on the first department, that is, the department for research. As a matter of fact, however, the second department is by far the larger. I found that, as far as labor and expenditures are concerned, they stand about as one to three; that is to every man in the research department, there are three men in the standardizing department; the expenses, it seems, are about in the same proportion.

I was interested in the standard of light which that institution has adopted, the Hefner amyl-acetate lamp. They seem to be quite well satisfied with it now, and say that it is more accurate as a standard than the usual measurements that are made with it on the photometer, and therefore it is a sufficiently good standard. They use it altogether, and it has been adopted in Germany as the standard both by the gas and by the electrical industries. This standard can be reproduced by constructing it according to scale, that is, according to measurements, it does not necessarily have to be calibrated; that is, if constructed exactly according to specifications one can be sure that it will give one candle without the necessity of calibration; for very accurate work they are calibrated by the Reichsanstalt. In our country we seem to have no real standard of light. It seems that at one of the large lamp factories in our country, the standard used was handed down through many years, in the form of incandescent lamps.

If we in this country should start a similar institution, I think it would be better to lay more stress on the second department of the Reichsanstalt, that is, the calibrating department, than on the research department, at least at first. I think the first department should follow the introduction of the second, and not precede it, because the second department will yield results at once, and will supply something which is much needed in this country.

I might add that I inquired whether they preferred the Weston cell to the Clark cell, and I found that they not only preferred it, but found it to be very much better. It seems that the Weston cell is now replacing the Clark cell altogether, due, of course, to the well known fact that the temperature coefficient is negligibly small. It was amusing to notice that nowhere did they call it the "Weston cell," as they did not seem to like to admit that it came from America. It is always called the "cadmium cell" there, although the other is called the "Clark," and not the "zinc cell."

DR. SAMUEL SHELDON:—Mr. President, I think that we as a scientific body, and any other scientific body, would strongly favor the founding in this country of an institution of this character. Certainly, if France, or if England, or if Russia, who are so near to the standards of the Reichsanstalt, can feel that it is necessary for them to found such an institution, we, who are over the ocean, who have such troubles in our Custom Houses, and who have such long delays in getting returns from the other side, ought to favor it. We, however, ought to consider that outsiders, and those who are not interested particularly in science, must be made to take an interest, before the object can be attained, and I hope some action will be taken before long, even further than that which has been already taken, to influence legislation in the proper direction. We certainly need such an institution merely for the calibration of instruments, not considering the idea of a research department. I don't know whether we ought to say that we can find in America the man who would make an institution in this country as renowned as is the Reichsanstalt in Germany. Think of the two men who have been at the head of that institution. Helmholtz was a prominent physician, a foremost physiologist, a superior physicist, in fact, a broad and cultured scientist. He was a man who would conquer anything, and who was especially fitted for this kind of a position. Kohlrausch—I had the pleasure of being his assistant for two years—is a man of the most wonderful scientific imagination, and in addition to that fact he criticises himself unsparingly. He was the most prominent advocate and supporter of the laboratory system of instruction in its early days. I think his little *Leitfaden der Praktischen Physik* was the first book on laboratory physics. Now two such men could not have failed to have brought renown to the institution with which they were

connected. I do not question but that we might find somebody who would do the same for us, if he were not hindered because of our methods of legislation and government.

That we have a need for some bureau of unquestioned authority has come to my attention in some work which I have done for two different companies along almost the same lines. The products which they turned out did not differ from each other to any great extent, not much over a tenth of a per cent., but the products of the one company differed by about two per cent. from the products of the other company. Their supposed standards, to which they referred, were not multiples or submultiples of the same unit.

DR. CHARLES AVERY DOREMUS:—If an associate may be allowed to speak on this question, I happened the other day to pick up some of Sir Humphrey Davy's works, and in an address before the Royal Institution in London he urged that funds be appropriated for original research. He claimed that the nation which owed its progress to scientific endeavor would never have its citizens suffer the humiliation of slavery; that "science for its progression requires patronage, but it must be a patronage bestowed, a patronage received with dignity." I have tried to quote some of his words. Surely nothing could be more dignified for the promotion of scientific research than that the nation should be the patron, and nothing could subserve the purposes of what has been contemplated by this paper better than to have the Government of the United States not imitate necessarily the Reichsansalt or bureaus of other Governments, but establish something of its own on lines peculiarly original, though duplicating perhaps some work of others. I would like to say as a chemist that considerable advance has been made for the standardization of chemical instruments. We have been at work through committees and the like for some years past, and we are now having numbers of vessels standardized at Washington by the Government, a small fee being paid for the same, and I am under the impression that this bill of Secretary Gage's contemplates the union of all such calibration methods. When we consider how largely our chemical industries have developed in the last few years, how enormously they are going to develop in the next few, how absolutely essential it is to have accurate instruments for measuring solutions, for verifying weights, for making all sorts of computations, it is quite evident that there is a field in that direction which is quite as important as the electrical field. I am under the impression that Congress has already been memorialized from the chemical side of the scientific professions, and if the different institutes and different scientific societies of this country were to act in unison, I am very certain that very fruitful results would issue, perhaps in the next session of Congress.

MR. TOWNSEND WOLCOTT:—I want first to speak about those lamps that the Navy Department sent over. As I understand, Mr. President, you say that the amyl-acetate lamp is exceedingly accurate; but is it easy to use in calibrating electric incandescent lamps?

THE PRESIDENT:—It is easier to use than any other standard.

MR. WOLCOTT:—The Navy Department had some lamps, I think ten primary standards and twenty secondaries, and a lot more tertiary standards. At first they had intended to have them all standardized by comparison with the amyl-acetate lamp, and then after they got them they were to use the primary standards only to standardize the secondary, and the secondary only to standardize the tertiary. The tertiary standard was the one they would really use in daily work, so as to preserve their primary standards as long as possible. But the Reichsanstalt said that they could not do them that way; at all events, it would be entirely too much work; they would compare one lamp with the amyl-acetate standard and compare all the others with that. It seemed to indicate that they found it a great deal more work to compare an incandescent lamp with the amyl-acetate lamp, than to compare one incandescent lamp with another. The amyl-acetate lamp and the incandescent lamp are not exactly the same color. With two incandescent lamps of exactly the same color—that is, the same temperature—you can set the carriage of the photometer, if it be Lummer-Brodhun type, to a single millimeter every time, set it three or four times, and get the same result; whereas, if there is the slightest difference in the color you cannot do that.

Then in regard to standardizing instruments in this country, the Signal Corps here in New York had a Wheatsone bridge, which was rather old, and they wanted it standardized, and sent it to the Coast Survey. It was standardized. That is, each coil was measured, but they had no facilities for adjusting the coils. It is a little better to know when a coil is out, to know just what it is than not to know at all, but it is not nearly so good as having it adjusted so that it is right. It is somewhat humiliating that we have in this country no government institution for adjusting instruments accurately, and the advantage that some such institution as the Reichsanstalt would confer if we had one here is manifest.

DR. LOUIS BELL:—As Chairman of the National Electric Light Association Committee on standardizing electric lamps, I would say that the question regarding standard of light is one of direct interest. The committee has definitely accepted the amyl-acetate standard as the ultimate standard to which light should be compared; but it is a fact that owing to the slightly reddish cast of the amyl-acetate lamp, comparisons are by no means easy, and I am not at all surprised that the Reichsanstalt preferred

to compare one or a few lamps rather than standardize a large number. It is, however, a wonderfully satisfactory standard to use aside from the question of the slight difference in color. The difficulty which our committee has found is not in settling upon methods or anything of that sort, but agreeing on any one systematic way of rating incandescent lamps, which will not cause a cat and dog row among the lamp manufacturers, who, for the most part, I am earnestly persuaded, are intent on turning out a good product, but are a little bit cautious about admitting any particular method of rating, which might at the present time or some future time have an unfavorable influence on the rating of some lamps. I think, however, that in the last year or two, manufacturers have been coming to realize more and more the meaning of a definite standard, and I feel sure that that difficulty is going to vanish. The committee is now pegging away at the problem, making arrangements to produce some primary standard lamps and supply them, but the difficulty which has been met so far has been very largely commercial, it being very hard to settle upon a rating of lamps, quite aside from the scientific problems involved in standardizing, which will not be a source of constant rows in the case of those who make and also those who use lamps. I think the question is settling itself very satisfactorily, and I have no doubt that by next year at the coming meeting of the National Electric Light Association the committee will be able to bring in a final report, and will also able to furnish carefully standardized incandescent lamps to all who desire them.

THE PRESIDENT:—In reply to a question which Mr. Wolcott brought up, I would say that the Reichsanstalt uses the amyl-acetate lamp only as a primary standard, for occasionally standardizing incandescent lamp secondary standards. When they make measurements of electric lamps, they always use these secondary standard incandescent lamps, and bring the voltage to the proper amount. The incandescent lamps are used far below their rated candle power, that is, at a much lower voltage than the normal. In that way they get a light of about the same color as that of the amyl-acetate lamps; the comparison then becomes easier and more accurate, and the standard lamps last longer. If I remember correctly, one of their standard lamps used in this way, has run for ten thousand hours, and is still of exactly the same candle power it was in the beginning.

CAPTAIN SAMUEL REBER:—I know that we all agree upon the establishment of a Standardizing Bureau in this country. The question which arises is: what action shall the INSTITUTE take to further the establishment of this Bureau? I know from the results of correspondence and conversation with officials of the Coast and Geodetic Survey in Washington that a bill, drafted by them, was sent by Secretary Gage to both the Senate and House of Representatives, and was introduced as House Bill No. 11350, on May 5, 1900, and as Senate Bill No. 4680, on May 14, 1900. The

copy I have shows that the measure is very complete and amply covers the ground.

THE SECRETARY:—I have a copy of it at the office, and I was looking it over to-day. In addition to the bill, it goes into details as to the staff and the salaries and number of employees, and also in addition to that letters from prominent men in various lines throughout the country, making quite a complete document that was printed by the governmont.

CAPTAIN REBER:—After an extended hearing before the Committee on Coinage, Weights and Measures of the House, the bill was favorably reported, but owing to the press of business at the close of the session it failed to pass. I would like to ask if the INSTITUTE cannot take some action in the way of urging its passage. If a committee were placed in charge of the matter they could decide whether it is advisable to take it up on the lines of the bill, and if so, to then act on the matter.

THE SECRETARY:—The Council has already appointed a committee, and one or more members of it have appeared before the Congressional Committee at Washington in advocating this measure. At a meeting of the Executive Committee to-day the Chairman was called upon to make a report as to what further steps were necessary, the idea of the Executive Committee being that it would perhaps be advantageous to enlarge the committee by putting on a member in each State, as far as we could, or something of that kind, in order to carry out this line of work in bringing the attention of Congressmen and Senators in various parts of the country to the importance of this measure.

DR. DOREMUS:—I would say that the American Chemical Society which is a national society, has taken this up, and that the different agricultural stations throughout the United States are highly interested in the matter, and that the Department of Agriculture, especially the chemical division of the Department of Agriculture in Washington, is extremely interested, and has pushed the matter quite some, so that there is a very good chance for proper influence to be brought to bear to show the necessity and the needs of the manufacturing community, and the scientific community, particularly, to get this bill properly presented to Congress, and I believe that our national societies would gladly cooperate.

MR. E. H. MULLIN:—I was speaking the other day to a Congressman, who is now serving his sixth term in Washington, about this very bill, and he told me that if deputations were to go down in support of the bill, it would be of the best service in January next. He also told me that the most practical means of urging this bill upon the various Congressmen was for each member of each institution such as this, to write to his local Congressman from his own home and bring that pressure to bear, and he also said a third thing, and that was that the Washington officials should keep as much in the background as possible.

He is in favor of the bill himself, and will do his utmost to help to pass it.

MR. FREDERICK V. HENSHAW:—It seems to me that there are some important factors in this question which possibly have not been brought up. I came in a little late, perhaps they were mentioned before. I do not wish in any way to belittle the effect of societies and scientific institutions on legislation, but I think they need a little more backing if anything is going to be accomplished satisfactorily. A good many societies have been working on the patent office question for a good many years, and I do not see that they have gotten any very satisfactory fruit. Now, if this Government Bureau is to be of great advantage to the manufacturers of this country, as I think everybody concedes it would be, there is one factor. If you can get the rich corporations and the men of influence interested in manufactures to use their weight, that would be one thing. Then there are the army and navy. I notice in Prof. Carhart's paper he speaks of a communication from the United States Navy in regard to standardizing. The navy is working towards various standards both in mechanical and electrical engineering features, and the Army of course is doing the same thing to a somewhat less extent. Now, if a bureau could be established which could fix the standards for both the army and navy, it would simplify a great many things, and be of great benefit, and if the engineer officers of those two Government departments were strongly in favor of this I think it would be a very great factor in the establishment of such a bureau.

CAPTAIN S. REBER:—In answer to the suggestion just made, I may say that as far as the army and navy are concerned, I know they are both very much interested in the establishment of this bureau.

As a result of practical experience I agree with the statement that a resolution of a society does have the weight with Congress that it perhaps should. Congressmen, as a rule, do not take interest in the advancement of pure science or its application, but are much more responsive to personal pressure than to a series of formal resolutions from a technical society.

MR. MULLIN:—How would it do to have a circular letter sent to all the members of our INSTITUTE asking each member of the INSTITUTE to write a letter to his local Congressman in support of this measure? As I have heard about the measure, it is this way: It so nearly passed at the last session that it would pass with proper pressure in the short session, but it is one of those measures that if it goes over for a year or so becomes one of the regular annuals in the House that they always think of passing, and never pass. You have an excellent opportunity now, and perhaps as good an opportunity will never occur again.

THE PRESIDENT:—This matter is in the hands of a Committee of the INSTITUTE; it came up to-day at the Council meeting, and

it was decided to ask the Chairman of that Committee to report on what the Committee considered to be the best action for the INSTITUTE to take. Any members having any suggestions to make, would do well to communicate with this Committee of the INSTITUTE.

DR. FRANCIS B. CROCKER:—I visited the Reichsanstalt some time ago, but the matter is so forcibly stated in Professor Carhart's paper, that there is very little to add in the way of an argument, and apparently the matter of bringing it favorably to the attention of Congress is in the hands of a committee. It seems to me there is not very much to be done. It appears to be the unanimous opinion of all our members here, and I think of the absent members, that it is a very desirable thing to bring about. In fact, it is so clearly true, that it is hardly necessary to add any testimony. The question has been up for a long time. I remember when Dr. Mendenhall was Superintendent of the Coast Survey he made a beginning in this movement to establish an electrical bureau or electrical department in the Bureau of Weights and Measures. I might add that this Government is not so very deep in barbarism as some of the speakers would imply. The Bureau of Weights and Measures has standards that are as good as those possessed by any country, and it is perfectly able to verify or to compare those standards with others that may be submitted to it. The Coast Survey of this country is a scientific department which has done most admirable work. In the measurement of base lines, for example, it is unexcelled, and its pendulum determinations of gravity are fully equal to those done anywhere else. So we already have started and started many years ago in this direction. It only remains to give additional assistance and money, to carry the work into the electrical field especially, and the chemical as well, in order to have a scientific department in Washington which would be very creditable. I think myself that the influence of the various national bodies, if brought to bear directly—if the committee report contained the official endorsement of the various bodies—I am sure that it would have weight. A Congressman is also affected by personal influence; but in a matter of this kind it is largely a question of whether it is a desirable thing to do or not. It is not a personal matter; it cannot be made a personal matter, and it seems to me that this body and other bodies should put themselves squarely on record, and that record should be, if possible, placed before the Congressional Committee, and attached to the bill in some form, and I am very sure it would have some weight. Of course adding to that the personal influence of the various members and bringing pressure to bear on the local Congressman would still further influence the result. But it seems to me the thing is so very desirable, that it is only necessary to bring it up to have it pass.

THE PRESIDENT:—If there is no further discussion, I will show briefly how the spherical candle power of incandescent lamps is measured at the Reichsanstalt. It is quite ingenious, but it may not be new. The lamp is placed in a horizontal position, in the axis of the photometer, and is stationary. Around the lamp are revolved two flat mirrors making a certain angle with the axis. The direct light is cut off by a black screen. The light which is measured is that which falls on the mirrors, and is reflected into the photometer. The advantage of course is that you do not revolve the lamp, and the filament is therefore always in exactly the proper position. In this country I believe the lamp is generally revolved. With high voltage lamps the filaments are rather long, and if you revolve such a lamp rapidly enough to get no flicker in the photometer, the filament is apt to bend over to one side, due to centrifugal force.

[Adjourned.]

[COMMUNICATION RECEIVED AFTER ADJOURNMENT.]

DR. A. E. KENNELLY:—There can be no doubt as to the great importance of the work which the Charlottenburg Institution has carried on through the last decade. The researches which have been carried on there have been of great value, not only to Germany, but also to the whole scientific world. The work of such an institution fosters scientific inquiry, indirectly promotes justice and morality, and directly aids ingeneering. There can be no doubt that such an institution in America would be a matter of national importance and advantage. Considering the enormous value to modern civilization of scientific knowledge in general and of engineering, or technical knowledge in particular, it is difficult to imagine a more useful type of institution than the Reichsanstalt. No public gift could be of greater public advantage than such an institution, unless, perhaps, a hospital or a university.

The founding and endowing of such an institution by Government would naturally depend for its economic justification upon the more purely utilitarian aspect of such a bureau as a national industrial asset. It would seem that, from this standpoint also, the expense incurred in such endowment would be justifiable. In the first place, one of the duties of such an establishment would no doubt be the care and comparison of all physical standards, such as those of length and mass, and which already require and receive appropriation from the national coffers. The institution would be, therefore, but a natural extension of a bureau already existing at Washington. In the second place, the institution would, if properly administered, be reimbursed of a large porportion of its expenses in the fees which it would receive for the comparison and standardization of chemical and physical apparatus for industrial purposes. The saving to the

community in expenses which are now rendered necessary by the want of a national standardizing bureau, would more than pay for the deficit, on any reasonable scale of expenditure. All this, however, naturally rests upon the assumption that such an institution was conducted and controlled on civil-service principles, as distinguished from political principles. If the bureau became a mere political office, a splendid opportunity for the fostering of knowledge, skill, accuracy, engineering and trade would be more than wasted.