able workers to visit libraries, to inspect manufacturing processes, and to attend the meetings of scientific societies.

There is one thing which a research board should avoid. It is, I am convinced, a mistake for a governing body to call for an annual list of publications from research laboratories. Nothing could be more injurious to the true atmosphere of research than the feeling of pressure that papers must be published or the department will be discredited.

What I have said so far may seem largely a recital of new difficulties, but they are not insurmountable, and to overcome them adds a zest to life. It would have taken too long to go more fully into details, and I have tried to avoid making my address a research syllabus, merely giving in general terms the impressions gained during the twenty years in which the St. Andrews Research Laboratories have been in existence.

I have confined myself to the first stage in the research development of the chemist. His future path may lead him either to the factory or to the lecture-room, and in the end the exceptional man will be found in the director's laboratory or in the professor's chair. However difficult these roads may prove, I feel that with the financial aid now available, supported by the self-sacrificing labors of those who devote themselves to furthering this work, he has the opportunity to reach the goal. It is the beginning of a new scientific age, and we may look forward confidently to the time when there will be no lack of trained scientific intellects to lead our policy and direct our efforts in all that concerns the welfare of the country.

J. C. IRVINE

THE UNITED STATES FUNDAMENTAL STANDARDS OF LENGTH AND MASS

THE recently published volume containing the testimony submitted to the Senate Committee on Manufactures, in favor of and against the passage of Senate Bill 2267 "To fix the Metric System of Weights and Measures as the Single Standard of Weights and Measures for Certain Uses," contains a mass of information and misinformation of great interest to students of metrology.

The opponents of the metric system were very active in marshalling their full strength at the numerous "hearings" before the subcommittee, about half of the volume being devoted to the evidence which they furnished, either in writing or in the form of personal testimony.

These are the pages which the well informed reader will certainly find most interesting, because of the remarkably illogical arguments introduced, the total disregard of historic facts and the apparently complete ignorance of the fundamental principles of the science of metrology.

This is especially true of the testimony of Mr. C. C. Stutz who, born in Italy of Swiss parents, seems to have been thought particularly fit to be chosen as the representative of the opposition, being the secretary of the American Institute of Weights and Measures, an organization created, as the secretary declares, "for the purpose of defending the existing American system of weights and measures against pro-metric propaganda,"—and also for the improvement of the same, though evidence of the latter objective seems yet to be forthcoming.

Mr. Stutz is especially agitated because, as he says, "the impression has been spread throughout the United States and abroad that the meter and not the yard is the legal standard here"—discussing that question at great length on pages 173-4-5-6 and again pages 318-19-20 of the Report of the Hearings. He creates an imaginary American "inch," contending that it is exactly the same as the English inch and hence the English yard and the American yard are identical.

In reference to this particular part of Mr. Stutz's voluminous testimony the statement of a few facts that are well known to most metrologists may be useful.

The constitution of the United States declares that Congress shall have power "to fix the standard of weights and measures," but Congress has never exercised that power, except in a few isolated instances, the most important being the adoption of the decimal system for the coinage and currency of the United States in 1785—with the subsequent adoption in 1828 of a material standard "troy

pound" for the regulation of the coinage, and the "act to define and establish the units of electrical measure," which became a law on July 12, 1894.

The failure of Congress to act when the importance of action was especially urged by Washington in a message to the first Congress, as it was later by Jefferson, Madison and Adams, was due to the general recognition of the unscientific character of the clumsy and burdensome system or systems then in use in the colonies (mostly derived from the then very imperfect English system) and a strong desire on the part of the "early fathers" (who seem at this distance to have been as wise as they were early) to put into our weights and measures the same simplicity of decimal ratio that has made our system of currency the best in the world.

In the absence of congressional action many of the states acted separately, establishing their own standards, thus creating much confusion. Some states took no action at all, the business of exchange of commodities by weight and measure being based upon units that had no authority except tradition and continued use.

In the mean time important work was to be done by the government itself, in which standards of authority and precision were required. By far the greater part of this, the collection of revenue and the survey of the coasts and the country as a whole, was under the jurisdiction of the Treasury Department, and to a bureau of this department, the Coast and Geodetic Survey, was assigned the duty of obtaining and caring for such standards of precision as could be obtained in Europe.

Among them was a brass bar, eighty-two inches in length, made by Troughton, of London, which was graduated in inches and tenths with a degree of accuracy probably as high as was at that time attainable. A careful examination of the divisions, however, revealed a considerable degree of irregularity, but it was finally decided (1830) that when the temperature of this bar was sixty-two degrees Fahrenheit the distance between the twenty-seventh and the sixty-third inch lines should be regarded as the standard yard by all of the various government bureaus in which measures of length were used.

It is important to note that there was no congressional action, no law passed, the fixing of this standard being done by the secretary of the treasury, on the recommendation of the superintendent of the coast survey, acting in the capacity of superintendent of weights and measures.

Its authoritative use, therefore, was restricted to operations in which the United States government was concerned. At the same time, as the result of the discovery of great discrepancies among the weights and measures actually in use at the principal custom houses, standards of mass and volume were established, the validity of which was restricted in the same way.

In order to reduce the confusion of standards in and among the several states, in 1836 the secretary of the treasury caused a complete set of all weights and measures adopted for use in the collection of revenue to be delivered to the governor of each state, hoping that through their adoption by state legislatures a good degree of uniformity might be secured. In many cases this followed and in some instances the treasury standards were accepted without legislation.

To recur now to the standard yard as represented on the Troughton scale, and its relation to the English standard: It was doubtless a copy, though not an exact copy, of what had been adopted by the English parliament in 1826 as the imperial yard of Great Britain. This was a bar on which the yard was engraved, made in 1760 by a mechanician named Bird and kept in the custody of the clerk of the House of Commons.

In 1834 the burning of the Parliament House destroyed this and other imperial standards stored therein, and thus the immediate ancestor of the Troughton scale disappeared.

It was found impossible to reproduce it with any degree of accuracy by finding the period of vibration of a pendulum as had been originally provided and recourse was had to several copies of it which had been made and

deposited elsewhere. In this way was created the imperial yard which is at present the standard of length in Great Britain.

Here, therefore, are two outstanding facts: First, assuming for the moment that the Troughton scale has some legal standing as a standard yard of the United States, it is *not* a copy of the standard yard of Great Britain and it is well known that it is not in agreement with that standard. Hence our inch can not be the same as the English inch.

Second, the Troughton scale has not and never had legal standing as a standard of length, authoritative over the whole country, and furthermore, it may be well to repeat that Congress has never passed an act to establish a standard yard or a standard inch, except indirectly, as will be explained later.

Thus the claim made by Mr. Stutz and his followers that the inch of the United States is identical with that of Great Britain has no foundation whatever in fact.

The use of the metric system of weights and measures throughout the United States was legalized by act of Congress in 1866 and it is an interesting fact that it is thus far the only general system of weights and measures that has full legal (though not compulsory) standing throughout the whole country.

The history of the so-called "Mendenhall Order" which seems to be so disturbing to the peace of mind of Mr. Stutz and others opposed to metrological reform is briefly as follows: a copy of what is known as the "Metre of the Archives" and also a copy of the kilogramme, both of platinum, came into the possession of the Coast Survey in 1821, through the interest of Albert Gallatin, and as years passed other standard measures were added to the collection, including copies of the imperial yard. The inferior character of the earlier standards as compared with those of later date led to the practical abandonment of their use wherever work of the highest degree of precision was attempted. Every metrologist knows that a material standard may have the backing of legal authority and at the same time be so crude and imperfect as to be useless for refined work.

Without going into the history of the International Bureau of Weights and Measures and the production of beautiful copies of the international standards, it is sufficient to say that on the receipt of the two copies allotted to the United States it was resolved to formally abandon the Troughton scale as a standard of length and adopt the international metre as the final standard of reference, for only in this way could work of high precision then being done in the United States (this included not only the operations of the Coast and Geodetic Survey and other bureaus of the government but practically all research work done at colleges and universities or by independent scientific workers) be "tied up" with that done in Europe, for even in England the metric system was and still is in universal use among scientific men.

In recognition of the really great importance of the event, it was arranged to have the seals (which had been put upon the containers of these standards before they left Paris) broken by the President of the United States.

This was done in the cabinet room of the executive mansion on the second of January, 1890, in the presence, also, of the Secretary of State and the Secretary of the Treasury, together with a number of invited guests, representatives of engineering and scientific societies and others especially interested in the science of metrology.

Thus Metre No. 27 and Kilogramme No. 20 were formally adopted as the national prototype metre and kilogramme.

In connection with the World's Fair in Chicago in 1893 there was held an International Electric Congress, associated with which was a "Chamber of Delegates" officially organized for the purpose of coming to an international agreement upon the definitions of units for electrical measure.

In view of the probable success of this movement and of the certainty that such definitions would be built upon a metric foundation, it was deemed wise to have definite recognition of these national prototypes as the fundamental standards of reference in all metrological operations in which the United States Government was concerned.

This was accomplished by the preparation and publication of Bulletin No. 26 of the Coast and Geodetic Survey, which became authori-

tative on the approval of the Secretary of the Treasury which it received on April 3, 1893.

The "bull's eye" of that announcement is found in the following sentence: "In view of these facts and the absence of any material normal standards of customary weights and measures, the office of weights and measures, with the approval of the Secretary of the Treasury, will in the future, regard the international prototype metre and kilogramme as fundamental standards, *and the customary units, the yard and the pound, will be derived therefrom* in accordance with the Act of July 28, 1866."

Mr. Stutz in his testimony before the committee quotes this sentence several times, referring to the last phrase, "in accordance with the Act of July 28, 1866," as evidence that the metre and kilogramme are not thus made fundamental units but are to be considered as dependent upon the inch and the pound, according to his personal interpretation of the Act of 1866. But by some unhappy chance, by accident or otherwise, he has invariably omitted the words italicised above, "the customary units, the yard and pound, will be derived therefrom," which nullify and completely reverse his argument.

His quotations are apparently made from a circular, No. 47 of the Bureau of Standards in which, according to his own words, it was not intended to reproduce the order as a whole. It is possible, therefore, that these very important words were omitted in that circular and Mr. Stutz shall have the benefit of the doubt, but if he had consulted the original order he would have found them.

There can be no doubt of their meaning and it is a fortunate thing that the legal relations established by the Act of 1866 are so very nearly correct that for all ordinary purposes of comparison (and there can be no other) they are sufficiently accurate.

Recalling the fact that when this Act was passed Congress had never defined the yard or the pound (except the Troy pound for use in the mint); that these words had, throughout the country as a whole, no definite meaning; and the further fact that at that time the metric system of weights and measures was in almost universal use, except in Great Britain and the United States, and that it was represented by precise material standards, it seems more probable than otherwise that the Act of 1866 itself put the country upon a metric basis, supplemented and completed as it was by the receipt and adoption in 1890 of the national prototypes.

In any event there can be no possible doubt as to the effect of the issue of Bulletin No. 26 in making them the fundamental standards for all metrological operations in which the national government is in any way concerned.

The opponents of the metric system are strangely silent regarding another Act of Congress, much more far-reaching and vastly more effective in putting the country upon a metric basis than anything which preceded it.

It is the Act of July 12, 1894 which defines the units of measure by means of which transactions amounting to many hundreds of millions of dollars annually are adjusted, furnishing the sole method of measuring output and consumption of one of the very largest and most important industries of the present day. No one has had the courage to suggest a revision or repeal of that Act, so as to put into it the sacrosanct inch and one of the numerous pounds, in place of the centimetre and the gramme. Watt, kilowatt, volt and ampere are now familiar terms. The great war produced an almost universal interest in metric units and caused many manufacturers to regret that their use had not been made compulsory long ago.

And now space above and around us is almost constantly disturbed by waves, the length of which, measured only in metres, is of vital interest to tens of thousands of people, old and young, rich and poor, who are finding out what a metre is and what goes with it, so that, take it all in all, it seems certain that the opponents of metrological reform are engaged in a hopeless task.

In their own words, "they have beaten it once," and perhaps they may beat it again, *but not many more times.*

T. C. MENDENHALL

RAVENNA, OHIO
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