The place of Louis A. Fischer in metrology has been so ably described in the Foreword to Miscellaneous Publication No. 64 that it is reproduced here verbatim.

As a matter of historical record, it is appropriate here to comment briefly upon Mr. Fischer's career as a metrologist, which began with his entry, in 1880, into the service of the Office of Standard Weights and Measures of the Coast and Geodetic Survey. Starting in the workshop, where he was trained in the fabrication of precise standards, he served in all branches of the work up to the making of the most accurate determinations of length and mass, and by 1898 he was in immediate charge of the weights and measures office. When the Bureau of Standards was established in 1901 that office was made a part of the new bureau, and in the new organization became the division of weights and measures of the Bureau of Standards. Mr. Fischer was at once made chief of this division, a position which he filled with conspicuous credit from that time continuously until his death in 1921, except while on duty with the United States Army during World War I.

Throughout the nearly 20 years of his service with the Bureau of Standards, Mr. Fischer was prominently identified with every movement in the United States having to do with the science of metrology or the supervision of commercial weights and measures. He became one of the world's foremost experts in the comparison of fundamental precision standards of length, his work at the International Bureau of Weights and Measures in the recomparison of certain meter bars being especially noteworthy and laying the foundation for a thorough intercomparison of all national prototypes with the international standard.

Mr. Fischer's services during the World War were of inestimable value. As technical advisor of the War Department in gauge standardization he was in large measure responsible for the efficient manufacture and inspection of munitions in the many plants throughout the country, by reason of his thorough practical knowledge of the subject and the tireless energy he displayed in standardizing and coordinating the manufacturing processes and the activities of the hundreds of establishments engaged in this vital work.

Nor were his achievements less noteworthy in the more prosaic field of supervision of the weighing and measuring devices used in everyday commercial transactions. Appreciating as he did the fact that fundamental standards of precision mean but little to the business life of a community until these standards are translated into accuracy at the merchants' counters, Mr. Fischer unceasingly devoted his energies to the task of developing efficient and comprehensive weights and measures supervision on the part of the several States and their local subdivisions, to which agencies the Congress has left the administration of this important function of government. As early as 1905 he conceived the idea of an annual conference of State and local officers charged with the control of weights and measures in their respective jurisdictions, and in that year called a meeting of such officers as were then engaged, directly or indirectly, in this work. This first meeting had a total attendance of but 11 persons, and it was before this small gathering that Mr. Fischer delivered the paper which is published herewith, and which has since become the classic reference on this subject. From its humble beginning, however, the Annual Conference on Weights and Measures has grown until today it is truly national in its scope, and numbers among its members weights and measures officers from all parts of the United States, as well as scores of others, representatives of business and industry, who are interested in its objects and accomplishments. With the Conference as one of the important mediums through which to work, Mr. Fischer was unceasing in his efforts to carry to others his own firm conviction of the tremendous importance to every community of adequate weights and measures supervision, and to instill into those intrusted with the administration of weights and measures laws his own high ideals of the responsibility which is theirs and of the service which they should render. As a result, it may truly be said that Louis A. Fischer is the father of what we know today as weights and measures control in the United States.

2. Early History of Weights and Measures in the United States

Throughout its early history, the United States Government showed extensive interest in uniform weights and measures; several efforts were made to secure international agreements in this field. This interest has continued through the years and is stronger now than ever before.

The history of the original Confederation of States and of the constitutional government of the United States reveals much evidence of the perplexities arising from the diversity of weights and measures among the States and of the desirability of a uniform system.

The weights and measures in common use in this country at the time of the American Revolution were practically all of English origin and were intended to be equivalent to those used in England at that period. The principal units were the yard, the avoirdupois pound, the gallon, and the bushel. More or less authentic copies of the English standards of the denominations mentioned had been brought over from time to time and adopted by the different colonies. Divergencies in these weights and measures were, however, quite common, due no doubt to the fact that the system of weights and measures of England was not itself well established, and hence the copies brought to this country were often adjusted to different standards.

That this condition was recognized very early is made evident by the Articles of Confederation, ratified by the colonies in 1781, which contained the following clause: "The United States in Congress assembled shall also have the sole and exclusive right and power of regulating the alloy and value of coin struck by their own authority, or by that of the respective States—fixing the standard of weights and measures throughout the United States— . . . ." This power was transferred to Congress by the Constitution of the United States, effective 1789, in article 1, section 8, which reads: "The Congress shall have Power . . . To coin Money, regulate the Value thereof, and of foreign Coin, and fix the Standard of Weights and Measures."

While Congress was not slow to take action in regard to coinage, it seems not to have been inclined to come to a decision in regard to weights and measures, though apparently willing enough to consider the subject. Washington, in his first annual message to Congress, January 1790,[1] stated that "uniformity in the currency, weights, and measures of the United States is an object of great importance, and will, I am persuaded, be duly attended to." In accordance with Washington's suggestion, the matter was referred to a select committee of the House of Representatives with instructions to prepare a bill, and it was also ordered that the matter be referred to the Secretary of State to prepare and report to the House a proper plan for establishing uniformity in the weights and measures.[2] Jefferson was then Secretary of State, and in response to the above request made a report, in which he proposed two distinct plans. The first was substantially to "define and render uniform and stable the existing system * * * to reduce the dry and liquid measures to corresponding capacities by establishing a single gallon of 270 cubic inches and a bushel of eight gallons, or 2,160 cubic inches * * *." The second plan was "to reduce every branch to the same decimal ratio already established for coin, and thus bring the calculations of the principal affairs of life within the arithmetic of every man who can multiply and divide plain numbers."[3]

No action was taken, however, by the House and in his second message to Congress, on December 8, 1790, Washington again called the attention of that body to the importance of the subject.[4] A few days later the House ordered that the Jefferson report, referred to above, be communicated to the Senate. On March 1, 1791, the Senate committee to which the matter had been referred reported that it would not be eligible to make a change in the weights and measures, as a proposition had been made to the French and British Governments to obtain an international standard.[5] This report was accepted and the matter rested there, although Washington, on October 25, 1791, repeated his former recommendations in his third annual message to Congress, in the following language:[6]

> A uniformity in the weights and measures of the country is among the important objects submitted to you by the Constitution and if it can be derived from a standard at once invariable and universal, must be no less honorable to the public councils than conducive to the public convenience.

[1] Messages and Papers of the Presidents **1**, p. 66.
[2] Congressional Register **3**, p. 106.
[3] Journal of the H.R., Childs & Swaine, p. 106.
[4] Messages and Papers of the Presidents **1**, p. 83.
[5] Journal of the Senate, p. 143; John L. Fenno.
[6] Messages and Papers of the Presidents **1**, p. 108.

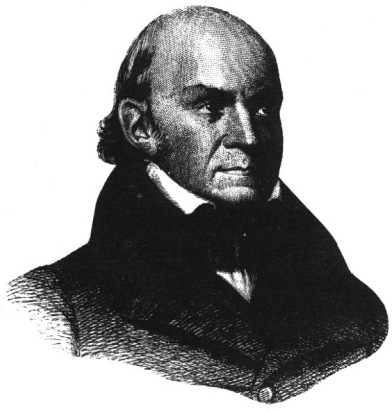
A week later the Senate appointed a committee to take into consideration the subject of weights and measures. The committee reported on the 4th of April 1792, recommending the adoption of the second plan proposed by Jefferson, which was an entirely decimal system. Again no definite action was taken. The matter was considered in a desultory way by Congress from time to time, but no agreement was reached notwithstanding that the repeated recommendations of Washington were followed by those of Adams. A sufficient explanation for the disinclination of Congress to act in a matter of such admitted importance was the difficulty of agreeing upon a plan.

The fifth Congress, second session, in 1799, passed an act ordering that the surveyor (of each port of the United States) "shall * * * from time to time, and particularly on the first Mondays in January and July in each year, examine and try the weights, measures and other instruments, used in ascertaining the duties on imports, with standards to be provided by each collector at the public expense for that purpose; and when disagreements and errors are discovered, he shall report the same to the collector, and obey and execute such directions as he may receive for correcting thereof, agreeably to the standards aforesaid * * *."[7]

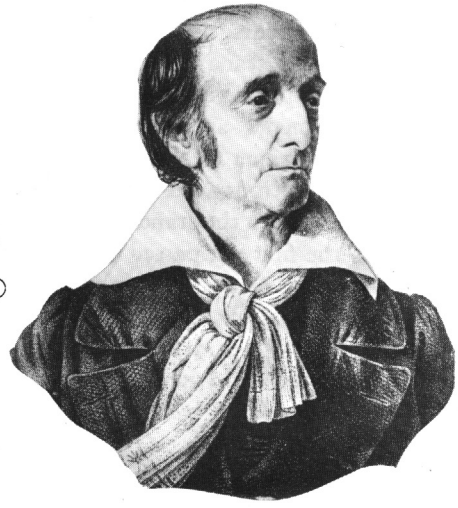
This was the first act passed by Congress in regard to weights and measures, but, in view of the fact that no standards had ever been adopted, the legislation was not put into operation until about thirty-five years after its passage, when certain standards, which will be referred to later, were adopted by the Treasury Department.

After the war of 1812 the question of uniformity in weights and measures was again brought to the attention of Congress, and in 1819 a committee of the House of Representatives proposed to adopt absolute standards conforming to the weights and measures in common use; to obtain through a commission copies of the yard, the bushel, the wine gallon, and the pound supposed to conform to those in common use in the United States; to preserve these standards and to distribute copies of them; to compare the length measure with the length of the second's pendulum and also with that of an arc of the terrestrial meridian; to connect them by determining the weight of a certain bulk of distilled water, and to define the bushel and the gallon by the weight of water which they contain.[8] No further record of the report is found, and it may be assumed that no action upon it was taken. The Senate had, by a resolution adopted March 3, 1817—two years prior to the above report—

[7] Statutes at Large **1**, p. 643.
[8] Executive Doc. No. 73, 30th Cong., 1st sess., Senate.

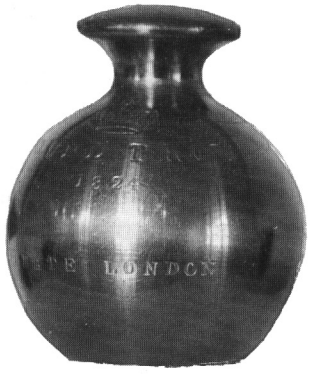


John Quincy Adams, 1767–1848.



Ferdinand Rudolph Hassler, 1770–1843.

(See also p. 6.)



Original troy pound of the mint.

This weight was legalized by act of Congress, May 19, 1828, as the "standard troy pound of the mint" to regulate the coinage. It was displaced as the standard for the coinage by act of Congress, March 4, 1911, when the "standard troy pound of the Bureau of Standards" was adopted for this purpose

requested the Secretary of State to prepare and report a "statement" relative to the regulations and standards for weights and measures in the several States and relative to the proceedings in foreign countries for establishing uniformity in weights and measures, together with such propositions relative thereto as might be proper to adopt in the United States.

John Quincy Adams was at that time Secretary of State, and four years later, on February 22, 1821, he submitted an elaborate report to the House of Representatives in which he reviewed the history of weights and measures in England, on the continent of Europe, and in the United States. He considered in detail the history of the metric system, and analyzed its merits and deficiencies. That system, a logical decimal system of weights and measures based upon measurements of a quadrant of the earth's meridian and the mass of a measured quantity of water, was one of the new ideas resulting from the French Revolution.

The basic unit of the metric system as originally conceived was to be a meter, a unit equal to one ten-millionth part of a quadrant of the earth's meridian as measured from the North Pole to the equator. A cube having sides of length equal to one-tenth of a meter was to be the unit of capacity, the liter, and the mass of a volume of pure water equal to a cube of one-tenth of a meter at the temperature of melting ice was to be the unit of mass, the kilogram.

The necessary measurements and the construction of standards was entrusted to committees ("commissions") composed of members of the Institute of France ("Institut National des Sciences et des Arts") and of deputies from other countries. The first undertaking was that of making extensive geodetic and astronomical measurements along a meridian from Dunkirk to Barcelona using the toise, an old French unit of length equal roughly to 6 U.S. feet and by modern measurements found to be equal to 1.949 090 meters, as the unit of length and computing the length of a quadrant of that meridian. From these results there was constructed a one-meter bar of platinum, the length of which was intended to be the one ten-millionth part of the length of the meridional quadrant. This bar, having its length defined by the distance between its two ends, became the "Meter of the Archives."

Twelve iron copies of this meter bar were constructed by a committee under the special direction of J. G. Trallès, the deputy from the Helvetic Republic. Two of these copies were assigned to Trallès, who then gave one, known in this country as the "Committee Meter," to his friend Ferdinand R. Hassler

who was selected by President Jefferson to be in charge of the Survey of the coast of the United States. As will be seen, this bar later played an important part in the weights and measures of this country.

After the Adams report had reviewed the status of weights and measures at home and abroad, including an analysis of the advantages and disadvantages of the metric system, it made a number of recommendations, the final ones being "1. To fix the standard, with the partial uniformity of which it is susceptible, for the present, excluding all innovation. 2. To consult with foreign nations, for the future and ultimate establishment of universal and permanent uniformity."

As before, Congress took no action, probably because the situation at that time was extremely complicated. Neither the metric system in France nor the system in common use in England was well established. In France, the law making the metric system compulsory had been repealed, and the metric system was in use side by side with the ancient weights and measures, thus producing endless confusion. In England the situation was not much better; the ale gallon of 282 cubic inches and the wine gallon of 231 cubic inches were both in use until 1824, when the new imperial gallon, containing 10 pounds of water, and of a capacity of about 277½ cubic inches, was adopted, together with the bushel of 8 gallons. Neither of these measures was in use in this country, and hence the United States could not at that time adopt either the system in use in England or the one in France without introducing radical changes in the weights and measures already in use, nor was there at that time any positive assurance that either the English or the metric system would be permanent.

While Congress had been considering the matter, most of the States had, independently of one another, secured and adopted standards. Most of the standards thus adopted were brought from England; nevertheless, standards of the same denomination differed widely among themselves, thus perpetuating confusion in the commerce between the States.

Though confusion in commercial transactions might be tolerated, uncertainty in regard to the coinage could not be tolerated, and on May 19, 1828, a certain troy pound was adopted as the standard for coinage by Congress in an "Act to continue the Mint at the City of Philadelphia, and for other purposes." Section 2 of this act reads as follows:

And be it further enacted, That, for the purpose of securing a due conformity in weight of the coins of the United States * * * the brass troy pound weight procured by the minister of the United States at London, in the year one thousand eight hundred and twenty-seven, for the use of the mint, and now in the custody of the Mint at Philadelphia, shall be the standard troy pound of the Mint of the United States, conformably to which the coinage thereof shall be regulated.

The troy pound thus adopted had been procured in 1827 by Albert Gallatin, United States minister at London, and brought to this country by special messenger, who delivered it to the director of the Mint at Philadelphia. The weight was of brass and an "exact" copy of the imperial troy pound of Great Britain, according to the statement of Captain Kater, who made the comparison between the two standards. The casket and accompanying packages were retained under seal until President Adams visited Philadelphia and verified Gallatin's seal and the other facts in regard to its authenticity.

This ceremony took place on October 12, 1827, and the full certificate of President Adams in regard to the seal, which he readily recognized, and to the whole transaction and consequent accuracy of the weight was added to the vouchers in the case. He declared, in conclusion, his belief that the brass weight then exhibited was the identical pound copy of the imperial standard troy pound of Great Britain. These facts were communicated to Congress through Committee on the Mint and resulted in the passage of the act cited above. This act was not modified until 83 years later, in 1911. A report of Samuel Moore on the original troy pound of the Mint, giving many interesting details, is reproduced in appendix 2.

While the act of Congress of 1828 only made this pound the standard for coinage, it virtually became the fundamental standard of the United States from which the avoirdupois pound in common use was derived.

On May 29, 1830, two years after the mint pound had been legalized for coinage, the Senate passed a resolution directing the Secretary of the Treasury to cause a comparison of the weights and measures in use at the principal customhouses to be made, and to report to the Senate at its next session.

Steps were promptly taken by the Treasury Department to comply with the resolution of the Senate. The preliminary report of F. R. Hassler, Superintendent of the Coast Survey, to whom the investigation had been intrusted, was transmitted to the Senate on March 3, 1831; [9] a more complete report followed in June 1832.

As was anticipated, large discrepancies were found to exist among the weights and measures in use at the different ports, some being too small and others too

[9] See H.R. Doc. No. 299, 22d Cong., 1st sess.

large, but the average value of the various denominations agreed fairly well with the weights and measures in use in Great Britain at the time of the American Revolution.

Without waiting for authority from Congress the Treasury Department took immediate steps to correct the situation by having constructed, under Hassler's direction, the necessary weights and measures for the customs service. The divergencies among the weights and measures in use in the customs service were directly opposed to the spirit of the Constitution, which requires that all duties, imposts, and excises shall be uniform throughout the United States,[10] and the Secretary of the Treasury felt fully authorized in taking steps to secure uniformity when discrepancies were found.

3. Units and Standards

Before weights and measures could be constructed, however, it was necessary for the Treasury Department to decide upon certain units and to adopt standards, that is, the material representatives of these units.

A clear understanding of the difference between "units" and "standards" will aid the reader in the sections that follow.

A *unit* is a determinate quantity (that is, one established by definition) in terms of which values, quantities, amounts, or magnitudes are expressed. Being fixed by definition, a unit is itself independent of physical conditions—as, for example, temperature—even though it may be defined in relation to some object that is affected by such conditions. Thus a particular unit of capacity may be defined as a volume of a specified number of cubic inches; the United States gallon is so defined—as a unit of 231 cubic inches. Or again, a particular unit of length may be defined as a distance corresponding to the interval between certain engraved lines on a certain metal bar when measured under specified conditions, including those of the support and the temperature of the bar; until October 1960 the meter unit was so defined in relation to the international meter bar.

A *standard* is the physical embodiment of a unit. In general a standard is not independent of physical conditions and is a true embodiment of the unit only under specified conditions. Thus a 1-gallon metal standard will have a capacity of 1 gallon only when the standard is at a certain temperature; at any other temperature the capacity of the standard will have been increased or decreased as a result of the expansion or contraction of the metal caused by the temperature change. Or again, a length standard having a nominal value of one yard will have an actual value of one yard only when at one particular temperature and when supported in a certain manner; a lowering of its temperature will cause the standard to shorten, a raising of its temperature will cause it to lengthen, and a change of the manner in which it is supported may introduce a change in its length.

When a unit is defined in terms of a standard, the latter acquires a fundamental character; the International Prototype Meter was such a standard until the meter unit was redefined in 1960. Standards are classified into groups, according to their character, the order of their accuracy, and the order of their legal or other importance. Thus there are, for example, international and national "prototypes," State "reference" standards, "laboratory working" standards, "field" standards, and various "classes" of standards established largely on the basis of design and accuracy.

4. Early United States Standards

The units finally adopted by the Treasury Department in 1832 were the yard of 36 inches, the avoirdupois pound of 7,000 grains, the gallon of 231 cubic inches, and the bushel of 2,150.42 cubic inches. The standard yard adopted was the 36 inches comprised between the 27th and the 63d inches of a certain brass bar, commonly designated as an 82-inch bar, prepared for the Coast Survey by Troughton of London. Hassler had brought this bar to the United States in 1815, after he had been detained in Europe for several years by the War of 1812. The 36-inch space referred to was supposed to be identical with the English standard at 62 °F, although it had never been directly compared with that standard.

It is evident from Hassler's reports that he regarded the English yard as the real standard of length of the United States and the Troughton scale merely as a copy whose length should be corrected if it was subsequently found to differ from the English yard; and this view was taken by others who subsequently had charge of our standards, as will be shown later on.

The avoirdupois pound adopted by Hassler as the standard for the Treasury Department was derived from the troy pound of the Mint according to the equivalent, 1 avoirdupois pound equals $\frac{7,000}{5,760}$ pounds troy. This was the accepted relation in this country as well as in England; hence both the troy and avoir-

[10] Article I, sec 8, clause 1.