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.

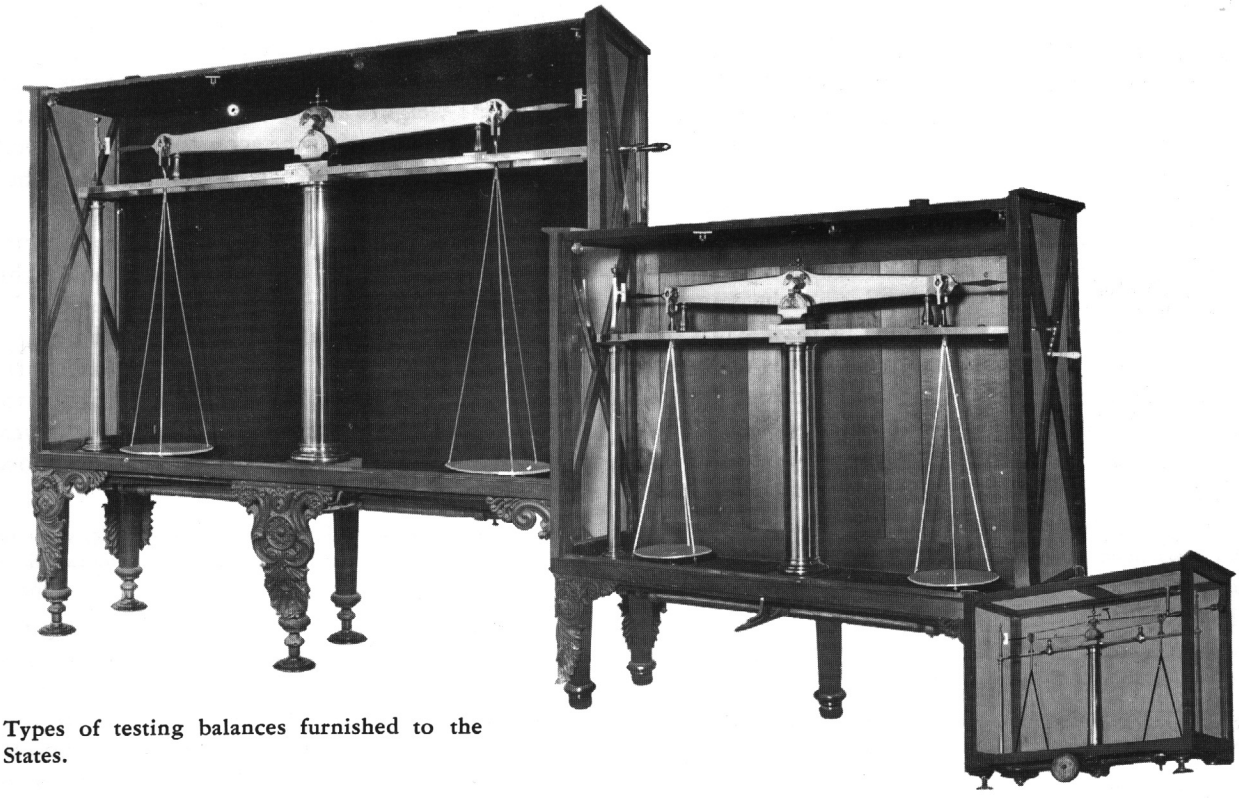
4. Early United States Standards

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-

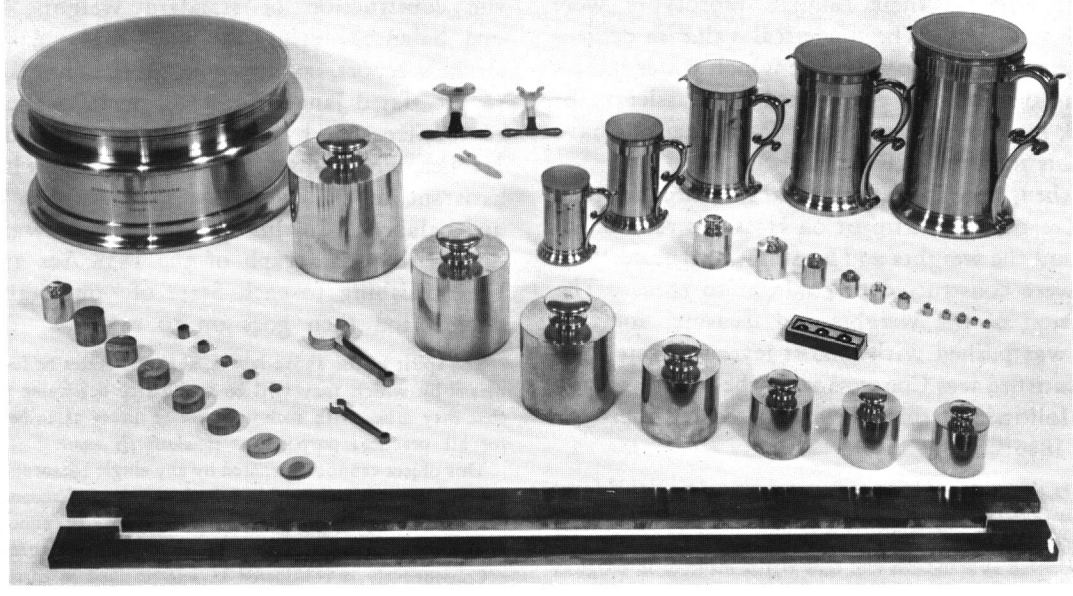
[10] Article I, sec 8, clause 1.



Types of testing balances furnished to the States.

Under the terms of an act passed in 1838 the Secretary of the Treasury was directed to furnish balances to the States. As furnished, a complete set of these balances comprised a 50-pound balance, a medium balance of about 10 pounds capacity, and a small balance of about 1-pound capacity. (See note 11, p 8.)

These balances are on display at the National Bureau of Standards.



Standards of length, mass, and capacity furnished to the States under the joint resolution of Congress of June 14, 1836.

In the illustration the half-bushel measure is at the upper left, the liquid measures—1 gallon to ½ pint—at upper right; slicker plates are in position atop each of these capacity measures. The 13 weights at the left are troy standards. Avoirdupois standards are above and to the right of the troy weights. In the foreground are the yard and matrix.

dupois pounds adopted were in practical accord with the similar standards of Great Britain.

The units of capacity, namely, the wine gallon of 231 cubic inches and the Winchester bushel of 2,150.42 cubic inches, were adopted because, as intimated, they represented more closely than any other English standards the average of the capacity measures in use in the United States at the date of Hassler's investigation. The wine gallon was introduced as a wine measure into England in 1707, during the reign of Queen Anne, but it was abolished in 1824, when the new imperial gallon, containing 10-pounds of water, was made the standard. This last statement applies also to the bushel of 2,150.42 cubic inches. This bushel is the earliest English capacity measure of which we have any record, a copy of it made by order of Henry VII being still in existence. But this bushel had also been abolished in England, it having been superseded by the bushel of 8 imperial gallons. Therefore neither the gallon nor the bushel adopted by the United States Treasury Department was in accord with the legal capacity standards of England, but they were smaller by about 17 percent and 3 percent, respectively, and these differences exist at the present time. Not only did they differ from the new standards in Great Britain, but they also differed from the discarded English standards from which they were derived for the reason that Hassler selected the temperature of the maximum density of water as the temperature at which the United States measures were standard, whereas their English prototypes were standard at 62 °F. The numerical value in degrees Fahrenheit of the temperature at which water has its maximum density was determined by Hassler to be 39.83 °F; later and more precise determinations have shown this to be 39.2 °F.

Such, then, were the fundamental standards adopted by the Treasury Department on Hassler's recommendation; and the weights and measures for the customs service were constructed to conform to these. The construction of the weights and measures for this purpose was pushed with almost feverish haste, and so well satisfied was Congress with the progress made that the following resolution was passed and approved June 14, 1836:

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he hereby is, directed to cause a complete set of all weights and measures adopted as standards and now either made or in progress of manufacture for the use of the several custom-houses, and for other purposes, to be delivered to the governor of each State in the Union, or such person as he may appoint, for the use of the States, respectively, to the end that a uniform standard of weights and measures may be established throughout the United States.

While the resolution does not specifically adopt the standards described above, its practical effect was to make them the standards for the United States, inasmuch as the weights and measures distributed to the States in accordance with the act were in almost every case adopted by the State legislatures soon after their receipt.

By 1838 the weights for the States were reported finished, and, during the following year, the weights for the customhouses were completed and delivered.[11]

The resolution of 1836 was supplemented by Congress by the act of July 7, 1838, an act having the original purpose "to provide for the support of the Military Academy of the United States for the year 1838." One of several amendments to this act, however, reads as follows:

That the Secretary of the Treasury cause to be made, under the superintendence of Mr. Hassler, one standard balance for each State, and that when completed he cause them to be delivered to the respective Governors for the use of the respective States.

It is interesting that under this authority balances in three capacities instead of one were built for the States, a large (capacity 50 pounds), a medium (capacity about 10 pounds), and a small (capacity 1 pound). A commentary on this departure from the specific terms of the statute is found in House Document No. 159, 28th Congress, 2d Session; this document comprises a report dated February 26, 1845, by A. D. Bache, Hassler's successor as Superintendent of Weights and Measures, on the progress made in the construction of standard weights, measures, and balances during the year 1844. Appended to Bache's report, as appendix A thereto, is a special report, dated January 4, 1844, made to the Secretary of the Treasury by Edward Hassler, a son of F. R. Hassler, who had served for some years as his father's assistant in the construction of weights, measures, and balances. In this special report Edward Hassler quotes that paragraph of the 1838 Act authorizing the furnishing to each State of "one standard balance," and then goes on to say:

The spirit of the above law is, that the States be furnished with means by which they will be enabled to determine any question that may arise, with such a degree of nicety as to be as valuable for all practical purposes as if *absolutely exact.*

This object cannot be secured by any single balance; consequently arises the necessity of seeking the best means of accomplishing the desired object. Experience has proved that it cannot be secured with sufficient accuracy by less thau three balances.

Consequently, I considered myself justified in carrying ont the spirit, and securing to the country the important and so-much-needed object of the law.

* * * * *

[11] H.R. Doc. 159, 28th Cong., 2d sess.

It is not clear from the records now available that each State received three balances, one of each capacity, but it is known that this was the case in some States, and it is presumed that the normal distribution was on the basis of three balances per State.

By 1850 practically all the States admitted to the Union had been supplied with complete sets of weights and measures, and, in addition, sets were presented to England, France, Japan, and Siam. As new States were admitted they were also supplied with sets of standards, the last of these sets being supplied to North Dakota in 1893. Two special sets of standards have since been prepared. One was presented to the State of Alaska in 1959 and the other presented to the State of Hawaii in 1960.

A list of the weights and measures comprising one of the original State sets is given below.

First. A set of standard weights composed of one each of the following:

Avoirdupois weights

pounds	*ounces*	*ounce*	*ounce*
50	8	0.05	0.0005
25	4	0.04	0.0004
20	2	0.03	0.0003
10	1	0.02	0.0002
5	[12] 0.5	0.01	0.0001
4	0.4	0.005	
3	0.3	0.004	
2	0.2	0.003	
1	0.1	0.002	
		0.001	

Troy weights

pound	*ounces*	*ounce*	*ounce*
1	10	0.5	0.005
	6	0.4	0.004
	5	0.3	0.003
	4	0.2	0.002
	3	0.1	0.001
	2	0.05	0.0005
	1	0.04	0.0004
		0.03	0.0003
		0.02	0.0002
		0.01	0.0001

(The avoirdupois and troy weights 0.05 ounce and smaller were made of silver wire.)

Second. A standard brass yard measure, with Matrix.

Third. A set of liquid capacity measures, consisting of one of each of the following, with its ground-glass cover.

1 gallon
½ gallon
1 liquid quart
1 pint
½ pint

Fourth. A brass standard half-bushel with a ground glass cover.

In order to carry out the provisions of the resolution of 1836 and the act of 1838 the Office of Weights and Measures had been established under the direction of the Superintendent of the Coast Survey. All the standards adopted at the beginning of the work, and subsequently, were in the charge of this Office, with the exception of the troy pound of the Mint, which remained at Philadelphia.

In October 1834, the British imperial yard and troy pound made in 1758, of which the Troughton scale and the mint pound were supposed to be exact copies, were destroyed by the burning of the Houses of Parliament. When the new imperial standards to replace them were completed in 1855 two copies of the yard and one copy of the avoirdupois pound were presented to the United States, arriving in this country in 1856. One of these bars, namely, bronze yard No. 11, was very soon after compared with the Troughton scale, the result showing that the accepted 36 inches of the Troughton scale was 0.00087 inch longer than the British imperial yard.[13] The second bar received from England was subsequently compared with the Troughton scale and fully corroborated the result obtained from the comparison with bronze No. 11. The new yards, and especially bronze No. 11, were far superior to the Troughton scale as standards of length, and consequently they were accepted by the Office of Weights and Measures as the standards of the United States, and all comparisons were afterwards referred to the imperial yard through these two standards. They were twice taken to England and recompared with the imperial yard, once in 1876 and again in 1888.

The avoirdupois pound presented with the two yards was also compared with the United States avoirdupois pound derived from the mint pound, the result showing a very satisfactory agreement. The advent of the new pound did not, therefore, disturb the position of the troy pound of the Mint, or of the avoirdupois pound derived from it. There is a reference concerning this comparison of the pounds made by Alexander D. Bache, Superintendent of Weights and Measures, in a report dated December 30, 1856 to

[12] The denominations of some of the weights were changed in sets supplied after 1857. Instead of decimal parts of the ounce, weights of the following denominations were furnished: ½ ounce, ¼ ounce, ⅛ ounce, and 1/16 ounce; 50, 25, 10, 5, 4, 3, 2, 1, 0.05, 0.04, 0.03, 0.02, and 0.01 grains.

[13] See Report of the Secretary of the Treasury on the construction and distribution of weights and measures in 1857. S. Ex. Doc. No. 27, 34th Cong., 3d sess.

the Treasury Department (34th Congress, 3d Session, Senate Executive Document No. 27, p. 18):

The copy of the British standard commercial pound was compared with the American standard commercial pound—the weight used being that made by Mr. Hassler from the troy pound in the United States mint, and marked with a star (commonly designated as the *star pound*).

In the standards vault of the National Bureau of Standards there is preserved a 1-pound avoirdupois brass knob weight marked on the top surface of the knob with a star. Although positive identification is not possible, it seems not unreasonable to assume that this weight is the standard referred to in the Fischer and Bache texts. (See illustration p. 22.)

At present there is no United States national prototype avoirdupois pound constituting the ultimate national reference standard for avoirdupois standards of lower order. Laboratory sets of avoirdupois standards are in use, but these are derived from the national prototype kilogram.

5. Use of Metric System Officially Permitted

The next and perhaps the most important legislation enacted by Congress was the act of 1866 legalizing the metric system of weights and measures in the United States.

The act, which was passed July 28, 1866, reads as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the passage of this act it shall be lawful throughout the United States of America to employ the weights and measures of the metric system; and no contract or dealing, or pleading in any court, shall be deemed invalid or liable to objection because the weights or measures expressed or referred to therein are weights or measures of the metric system.

SEC. 2. *And be it further enacted*, That the tables in the schedule hereto annexed shall be recognized in the construction of contracts, and in all legal proceedings, as establishing, in terms of the weights and measures now in use in the United States, the equivalents of the weights and measures expressed therein in terms of the metric system; and said tables may be lawfully used for computing, determining, and expressing in customary weights and measures the weights and measures of the metric system.

(See tables on facing page.)

While the above act was being considered, Congress also considered a resolution authorizing the Secretary of the Treasury to furnish the States with metric weights and measures. Strange to say, this resolution, which logically should follow, was approved one day before the act legalizing the use of the metric system. It was a joint resolution and read as follows:

Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he is hereby, authorized and directed to furnish to each State, to be delivered to the governor thereof, one set of standard weights and measures of the metric system for the use of the States, respectively.

The work of making and adjusting these standards fell naturally upon the Office of Weights and Measures, and the first matter to be resolved was the choosing of the reference standards. The practice followed by those countries that had adopted the metric system of accepting the meter and the kilogram of the Archives of France as fundamental standards was followed by the United States. The question then was mainly one of securing authentic copies of these standards. Fortunately the Office of Weights and Measures had several copies of both standards of more or less authenticity on hand, but without hesitation the iron bar known as the "Committee Meter" and a platinum kilogram, known as the "Arago Kilogram," were selected.

The committee meter has already been mentioned as being one of the copies of the meter of the Archives, and thus a standard of considerable importance in the metric system. As stated before, this bar is made of iron, with a cross section of 9 by 29 mm, and its length is defined by the end surfaces, which are remarkably plane when one considers the age in which the bars were made. The bar bears the stamp of the committee, namely, a small ellipse. Three quadrants of the ellipse are shaded and the fourth one clear, except for the number 10,000,000, which indicates the number of meters in a meridian quadrant of the earth. In Hassler's report on the construction of the meters [14] it is stated, on the authority of Trallès, that all the meters agreed with the true meter within one-millionth part of the toise.[15] This is equivalent to about two millionths of a meter, the toise being equal to approximately 1.95 meters.

When Hassler came to the United States in 1805 he brought with him the committee meter, which he soon after presented to the American Philosophical Society of Philadelphia, Pa. Shortly after, when he was put in charge of the survey of the coast, the meter was placed at his disposal by the Philosophical Society, and he made it the standard of length for that work. Until 1890 all base measurements of the Coast Survey were referred to this meter.[16] Thus it was natural that this bar should be selected as the standard to which the State meters should conform.

[14] H.R. Doc. No. 299, 22d Cong., 1st sess., pp. 75, 76.

[15] The toise was the French standard of length prior to the adoption of the meter, and all the geodetic measurements upon which the meter was based were made with the toise. Its length is 1.949+meters.

[16] Special Publication No. 4, U.S. Coast and Geodetic Survey.