9. Wavelength Definition of the Meter

It is obvious that exactness in units must have its basis in standards that are as permanent and exact as possible. Ever since 1890 when Michelson made his famous measurements of the wavelength of light in terms of the meter, metrologists have been giving consideration to the idea of defining the meter in terms of the wavelength of light. Researches by many scientists have been carried out to find a wavelength generally acceptable for use as an ultimate standard and to specify the conditions of its use. Finally, on October 14, 1960, the 11th General Conference on Weights and Measures adopted a new definition of the meter as 1 650 763.73 wavelengths of the orange-red radiation of krypton 86, or more specifically in scientific terms, as 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton 86 atom.

The National Bureau of Standards has adopted this definition (see appendix 6, p. 30), and thus it will not be necessary for the United States prototype meter No. 27 to be taken to the International Bureau for comparison as has been done in the past—in 1903,[18] 1922, 1956, and 1957—where its relation to the international prototype meter has been found to remain essentially constant.

The international prototype meter will continue to be maintained at the International Bureau and comparison of national prototypes with it will continue to be made. Likewise, the national prototype meters at the National Bureau of Standards will continue to be used for many precise calibrations of length standards.

An interesting sidelight on the change in the definition of the yard is found in measurements made just prior to April 1893 indicating that

1 U.S. yard=0.914 399 80 meter

or

1 meter=39.370 09 U.S. inches

a relation which differs by only 2 parts in 9 million from the value finally adopted in 1959. The observers, however, had in mind the value given in the 1866 law and noted that the value 1 meter=39.3700 inches "is evidently sufficiently precise for geodetic purposes and has the advantage of being convenient and easily remembered."

Although some thought has been given to a possible definition of the kilogram in terms of some invariable physical phenomenon instead of in terms of a material standard, no satisfactory solution has yet been discovered. The U.S. national prototype kilogram No. 20 was compared with international standards in 1937 and 1948 with excellent results.

10. Other Definitions of Units

Three other changes in the weights and measures field have occurred during the past 60 years. First, there was the change made in 1911 in the law defining the troy pound. At that time the words "the standard troy pound of the Bureau of Standards of the United States" were substituted for the description of the troy pound of the Mint.

Next, in 1913, the international metric carat was defined as the equivalent of 200 milligrams, thereby eliminating the use of a number of unofficial or semi-official carats.

Third, in 1954, the Secretary of Commerce and the Secretary of Defense agreed to use the international nautical mile in their respective departments instead of the older U.S. nautical mile. (See appendix 4, p. 28.) The practical effect of this action was that the use of the U.S. nautical mile has virtually disappeared.

11. Current and Historical Standards of Length and Mass at the National Bureau of Standards

This history of weights and measures in the United States concludes with a descriptive list of some of the more important standards of length and mass either (a) currently in use or (b) not in current use but of historical interest, that are in the custody of the National Bureau of Standards.

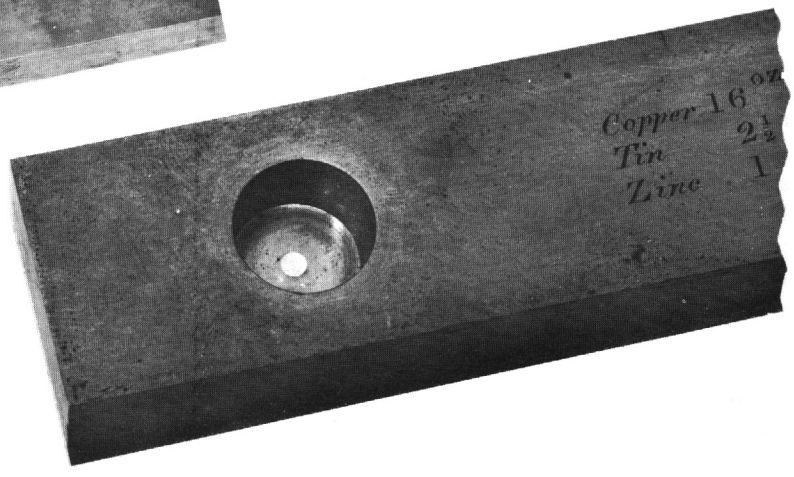
Standards Currently in Use

Meter 27.—National prototype meter, a line standard made of platinum-iridium, Tresca cross section (modified X), received by the United States from the Inter-

[18] In 1903 there was an apparent shortening of approximately 0.4μm in meter bar No. 27, but subsequent observations showed that there had been no shortening of this bar, but rather a lengthening of the two laboratory meter bars used in the comparisons and small errors in the coefficients of thermal expansion of the bars involved.

Troughton Scale.

The central portion of the scale is illustrated.



Bronze Yard No. 11.

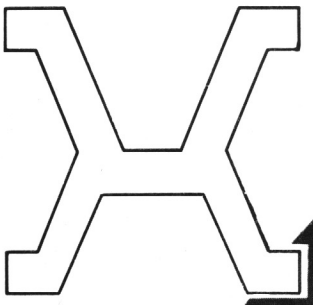
The left, or zero, end of the bar is illustrated.

Low Moor Iron Yard No. 57.

The left, or zero, end of the bar is illustrated.

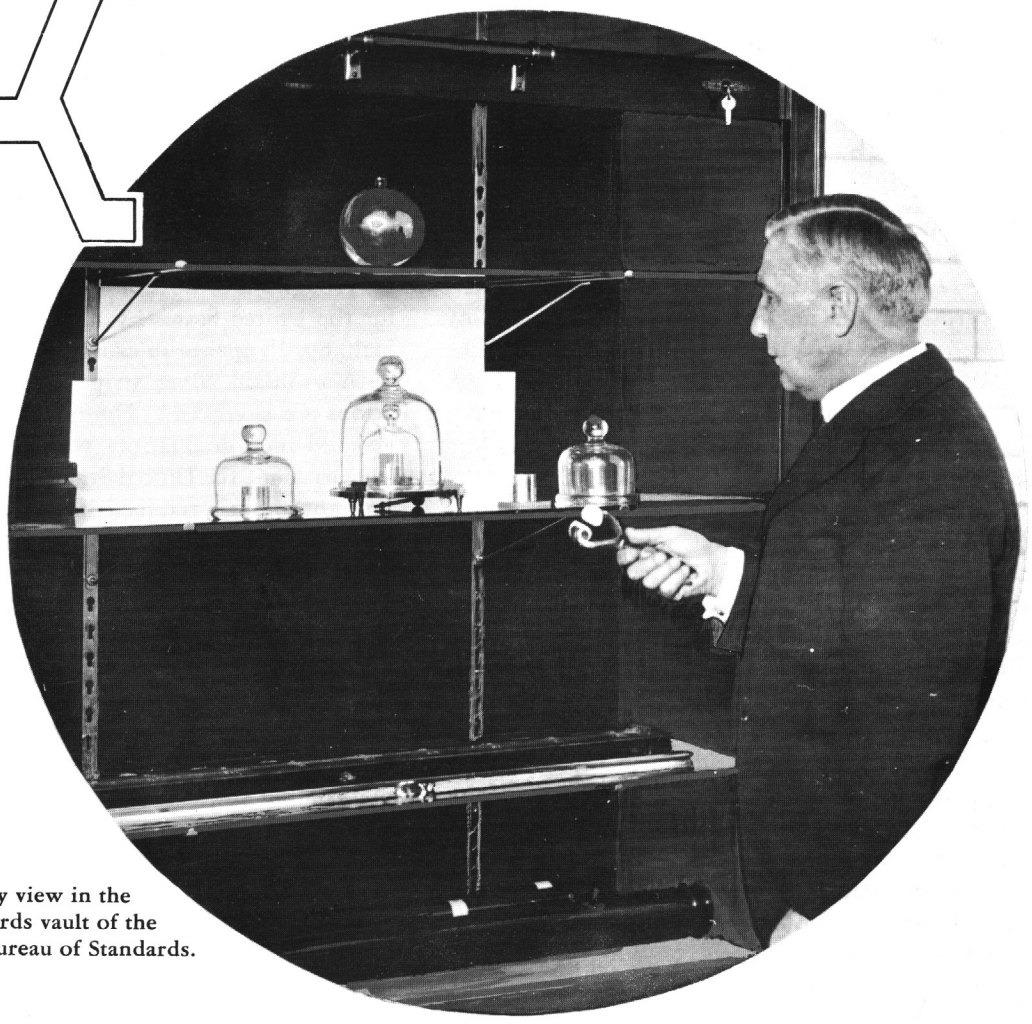
The grave.

"Star" avoirdupois pound.



Tresca cross section.

(twice size)



Early view in the standards vault of the National Bureau of Standards.

Formerly the national prototype standards of length and mass were kept in a cabinet at one side of the standards vault, as here illustrated. This view shows Louis A. Fischer, first Chief of the Division of Weights and Measures of the Bureau and, as such, custodian of the national prototype meter and kilogram.

Imperial avoirdupois pound, copy No. 5.

Front and top views

national Bureau of Weights and Measures in 1889. This meter was the United States national reference standard for all length measurements from 1893 to 1960, and in 1960 became the primary bar, secondary only to the basic value of the meter in terms of the wavelength of Kr^{86} light.

Meter 21.—National prototype meter of same material and design as Meter 27, received by the United States from the International Bureau of Weights and Measures in 1890.

Meter 12.—A platinum-iridium line-standard meter, Tresca cross section (modified X), made of the "Alloy of 1874," and received by the United States from the International Bureau of Weights and Measures in 1889. It was regraduated in 1948 by the National Bureau of Standards in terms of the wavelength of red cadmium light.

Meter 4.—A platinum-iridium graduated line-standard meter, Tresca cross section (modified X), made of the "Alloy of 1874," and purchased by the United States in 1907. It is graduated to 1-millimeter divisions for the entire 1-meter interval and is of special utility in making comparisons of intervals of less than 1 meter.

Kilogram 20.—National prototype kilogram, a mass standard made of platinum-iridium in the form of a cylinder of equal diameter and height, received by the United States from the International Bureau of Weights and Measures in 1889. It has been the United States national reference standard for all mass measurements since 1893.

Kilogram 4.—National prototype kilogram of same material and design as Kilogram 20, received by the United States from the International Bureau of Weights and Measures in 1890. It is secondary to Kilogram 20.

Standards of Historical Interest

Committee Meter.—An iron end standard of length, 9 millimeters by 29 millimeters in cross section. This bar is one of a group of similar bars made in France in 1799 by the committee that made the Meter of the Archives, whence its designation in the United States as the "Committee Meter." This particular bar was presented by Trallès, the Swiss member of the committee, to his friend F. R. Hassler; Hassler, in turn sold it to a member of the American Philosophical Society in Philadelphia, who deposited it with the Society. Later the bar was obtained from the Society by Hassler for the use of the U.S. Coast and Geodetic Survey, where it was used as the standard for scientific work in the United States from 1807 to 1893.

Arago Meter.—A platinum line standard of length, 5 millimeters by 25 millimeters in cross section. The bar was procured from France in 1821 by Albert Gallatin, Minister of the United States to France; it derives its designation from the name of the eminent French physicist who certified the length of its graduated interval. It appears that this bar has received essentially no use as a standard in the United States.

Troughton Scale.—A graduated line standard of length, commonly designated as an 82-inch bar, made by Troughton of London in 1814 and procured in 1815 for the United States by F. R. Hassler. The bar, ½ inch by 2½ inches in cross section, is made of brass with an inlaid silver strip on which $\frac{1}{10}$-inch graduations are engraved. The interval between the 27th and 63d inch graduations was selected by Hassler in 1832 to define the United States standard yard, and the Troughton Scale retained its position as the primary reference yard standard of the United States until about 1857.

Bronze Yard No. 11.—A bronze line standard of length, 1 inch by 1 inch in cross section, having an overall length of 38 inches. Near each end of the bar is a cylindrical well with an inset gold plug, the upper surface of the plug being ½ inch below the top surface of the bar. The 1-yard defining lines are engraved on the gold plugs. This bar is of the same material and form as the British Imperial Yard legalized in 1855, and was presented to the United States by Great Britain in 1856. It was used as the standard yard of the United States from about 1857 to 1893.

Low Moor Iron Yard No. 57.—An iron line standard of length, similar in design and construction to Bronze Yard No. 11. It was presented to the United States by Great Britain in 1856, and was in use in the United States as a standard until 1893, being regarded as secondary in importance to Bronze Yard No. 11.

Committee Kilogram.—A brass standard of mass, cylindrical, with knob. This standard is one of a group of similar standards made in France in 1799 by the committee that made the Kilogram of the Archives, whence its designation in the United States as the "Committee Kilogram." This standard was presented by Trallés, the Swiss member of the committee, to his friend F. R. Hassler; Hassler, in turn, sold it to a member of the American Philosophical Society in Philadelphia, who deposited it with the Society. Later, the standard was obtained from the Society by Hassler, who made use of it in connection with his standards work for the U.S. Coast and Geodetic Survey.

Arago Kilogram.—A platinum kilogram made in France by Fortin and certified by Arago. It was pro-

cured in France in 1821 for the United States by Albert Gallatin, Minister of the United States to France. Prior to 1890, this kilogram was used as one of the standards of the United States.

Silbermann Kilogram.—A gilded brass standard of mass, cylindrical, with knob. This standard was presented to the United States by France in 1852, and became a secondary standard in the Office of Standard Weights and Measures of the U.S. Coast and Geodetic Survey, used particularly in connection with the adjustment and verification of metric standards supplied to the States.

Grave.—A cylindrical knob weight, one of six made in 1793 by the French Temporary Commission on Weights and Measures as representing the unit of weight of a proposed system of weights and measures. Originally called the "grave", in 1795 the unit was renamed the "kilogram." This weight is from a set of weights brought to the United States in 1793, and it appears that the set came into the possession of one Andrew Ellicott, at one time an assistant to Major Pierre Charles L'Enfant who planned the city of Washington. The subsequent history of this set of weights is somewhat obscure, but it seems probable that the set remained in private hands, probably within the Ellicott family, until 1952, when what remained of the set was donated to the National Bureau of Standards by its owner at that time, Dr. A. Ellicott Douglass of the University of Arizona.

"Star" Avoirdupois Pound.—A cylindrical knob weight marked on the top surface of the knob with a star. Although positive identification cannot be made, it appears not unreasonable to assume that this standard is the actual weight "made by Mr. Hassler from the troy pound in the United States mint, and marked with a star (commonly designated as the *star pound*)," as referred to by A. D. Bache, Superintendent of Weights and Measures, in his report of December 30, 1856, to the Secretary of the Treasury.

Imperial Avoirdupois Pound, Copy No. 5.—A gold-plated brass standard of mass, cylindrical in form with a circumferential groove (instead of a knob) to facilitate handling. This standard was received in 1856 as a gift from Great Britain to the United States. It was used as the standard representing the United States avoirdupois pound from 1856 to 1893.

* * * * *

12. Addendum (The period 1963–1975)

Three Laws that have been enacted since 1963, the original date of publication of Miscellaneous Publication 247, are worthy of note:

Public Law 89–755, the Fair Packaging and Labeling Act. This Act, signed into law on November 3, 1966, became effective July 1, 1967. Section 2 of this Act reads as follows:

> "Informed consumers are essential to the fair and efficient functioning of a free market economy. Packages and their labels should enable consumers to obtain accurate information as to the quantity of the contents and should facilitate value comparisons. Therefore, it is hereby declared to be the policy of the Congress to assist consumers and manufacturers in reaching these goals in the marketing of consumer goods."

The authority to promulgate regulations under the Act was vested in the Secretary of Health, Education, and Welfare and the Federal Trade Commission. The Secretary of Commerce was authorized to furnish to state officers and agencies information and assistance to promote to the greatest practicable extent uniformity in State and Federal regulation of the labeling of consumer commodities.

Recognizing the need for compatibility with the Federal Act, the Committee on Laws and Regulations of the 53rd National Conference on Weights and Measures in 1968 amended the Model State Packaging and Labeling Regulation (first adopted in 1952) to parallel regulations adopted by Federal agencies under the Fair Packaging and Labeling Act. The process of amending and revising this model regulation is a continuing one, in order to keep it current with practices in the packaging field and make it compatible with appropriate Federal regulations.

Federal and State mandatory provisions require that all packages shall declare the identity of the commodity and the name and place of business of the manufacturer, packer or distributor; and the net quantity of contents (in terms of weight, measure or numerical count) shall be separately and accurately stated in a uniform location upon the principal display panel. In 1974, the model regulation was amended to provide for uniformity in the use of metric symbols and is currently being revised to fully accommodate the conversion to the metric system.