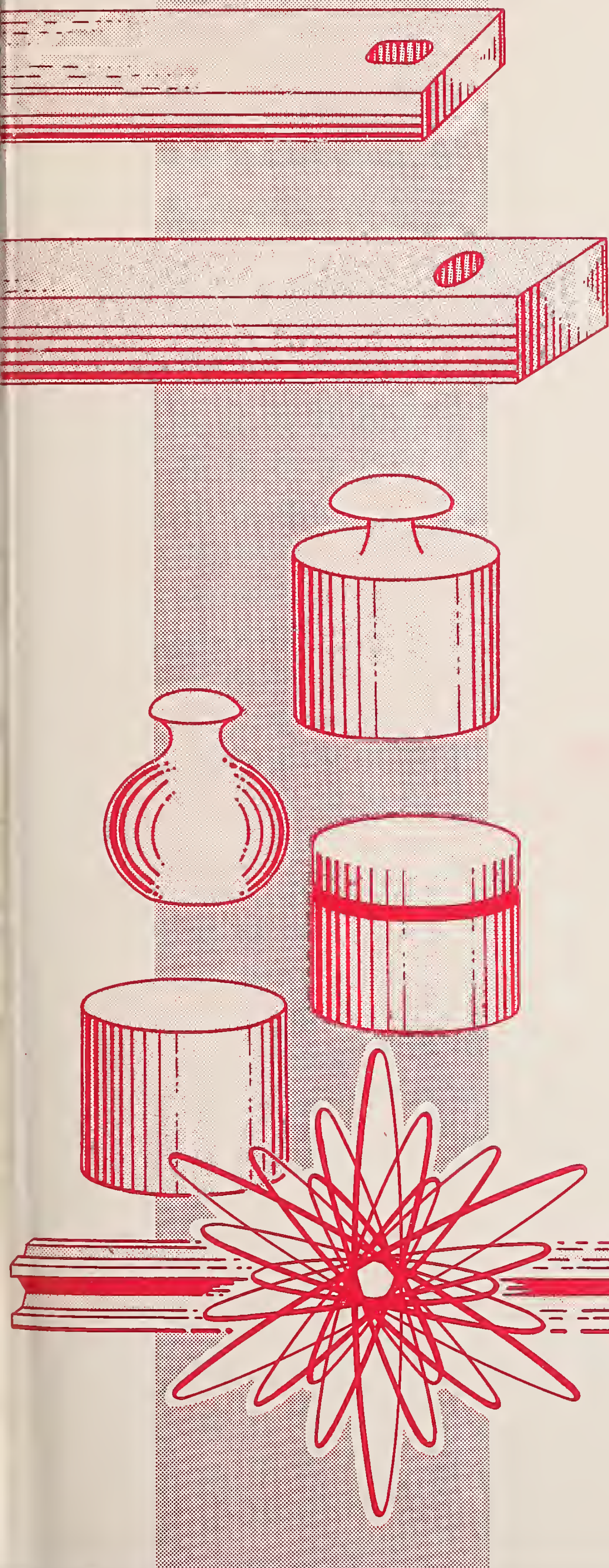

WEIGHTS and MEASURES STANDARDS OF THE UNITED STATES

a brief history

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NBS Special Publication 447

U.S. Prototype Kilogram 20, the standard of mass of the United States.

U.S. Prototype Meter Bar 27, the standard of length of the United States from 1893 to 1960. On October 14, 1960, the meter was redefined in terms of a wavelength of the krypton 86 atom.

Kr^{86}

WEIGHTS and MEASURES STANDARDS OF THE UNITED STATES

a brief history

LEWIS V. JUDSON

NBS Special Publication 447

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Foreword

"Weights and Measures," said John Quincy Adams in 1821, "may be ranked among the necessaries of life to every individual of human society." That sentiment, so appropriate to the agrarian past, is even more appropriate to the technology and commerce of today. The order that we enjoy, the confidence we place in weighing and measuring, is in large part due to the measurement standards that have been established. This publication, a reprinting and updating of an earlier publication, provides detailed information on the origin of our standards for mass and length.

ERNEST AMBLER
Acting Director

Preface to 1976 Edition

Two publications of the National Bureau of Standards, now out of print, that deal with weights and measures have had widespread use and are still in demand. The publications are NBS Circular 593, The Federal Basis for Weights and Measures (1958), by Ralph W. Smith, and NBS Miscellaneous Publication 247, Weights and Measures Standards of the United States—a Brief History (1963), by Lewis V. Judson.

To meet the current demand for information on the history of weights and measures in the United States, Miscellaneous Publication 247, referred to above, updated where needed to bring it into accord with current usage, is reprinted in this Special Publication, together with a brief addendum that discusses important events involving weights and measures of the period 1963–1975, immediately following the original date of publication of MP 247. NBS Circular 593 is not being reprinted because of the significant overlap of material treated in the two publications. Those interested in a detailed account of the Federal legislative background in the field of weights and measures units and standards should refer to NBS Circular 593 in one of the more than 100 depository libraries throughout the country.

Louis E. Barbrow

Preface to 1963 Edition

In 1905, Louis A. Fischer, then a distinguished metrologist on the staff of the National Bureau of Standards, presented a paper entitled "History of the Standard Weights and Measures of the United States" before the First Annual Meeting of the Sealers of Weights and Measures of the United States. This paper quickly came to be considered a classic in its field. It was published by the National Bureau of Standards several times—most recently in 1925 as Miscellaneous Publication 64. For some time it has been out of print and in need of up-to-date revision. The present publication covers the older historical material that Fischer so ably treated; in addition, it includes a brief summary of important later developments affecting the units and standards for length and mass. (Liberal use of Mr. Fischer's text is made in this publication.)

Lewis V. Judson.

Contents

Weights and Measures Standards of the United States

a brief history

Lewis V. Judson

A historical account is given of the standards of weights and measures of the United States from the time of the American Revolution through the year 1962.* Current and historical standards of length and mass now in the possession of the National Bureau of Standards are listed and described.

1. Introduction

When a housewife buys a quart of milk, when a midwestern farmer sells his grain crop—in all present-day commercial transactions—there is an implied faith that as goods are exchanged for money there is the same just balance for buyer and seller. In the early days of this country such faith was often lacking. Great variation existed in the weights and measures used in different localities, and even, at times, in those used by different individuals in the same locality. The transition from this chaotic situation to the present uniformity of weights and measures has resulted from the establishment of accurate, reliable national standards of length and mass and the enactment of comprehensive weights and measures statutes.

The present highly precise, and extremely stable national standards for these quantities were not achieved overnight, or even in a decade. They are the results of a long period of gradual evolution based on the dedicated efforts of men who recognized the growing need for accuracy of measurement. The story of this development is an interesting one that is of considerable historical importance, and is told in the pages that follow.

In 1905, Louis A. Fischer, then Chief of the Metrology Division of the National Bureau of Standards, presented a historical treatment of the United States standards of weights and measures before the First Annual Meeting of the Sealers of Weights and Measures of the United States. Although a great deal has occurred in weights and measures since then, Fischer's account has come to be considered a classic and will be used freely in the present publication, either verbatim or with such modifications as seem appropriate.

Fischer's paper was published first in the Proceedings of the First Annual Meeting of the Sealers of Weights and Measures (now the National Conference on Weights and Measures), then published in volume 1 of the Bulletin of the Bureau of Standards, then as a reprint designated as Scientific Paper No. 17 of the Bureau of Standards, and finally as Miscellaneous Publication No. 64 of the National Bureau of Standards, an illustrated edition of the address designated as a memorial to Fischer. Even though this last publication has long been exhausted, demands for it still continue, emphasizing the present need for an up-to-date historical treatment.

* The addendum on page 25 covers the period 1963–1976.

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.

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—

[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.
[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.

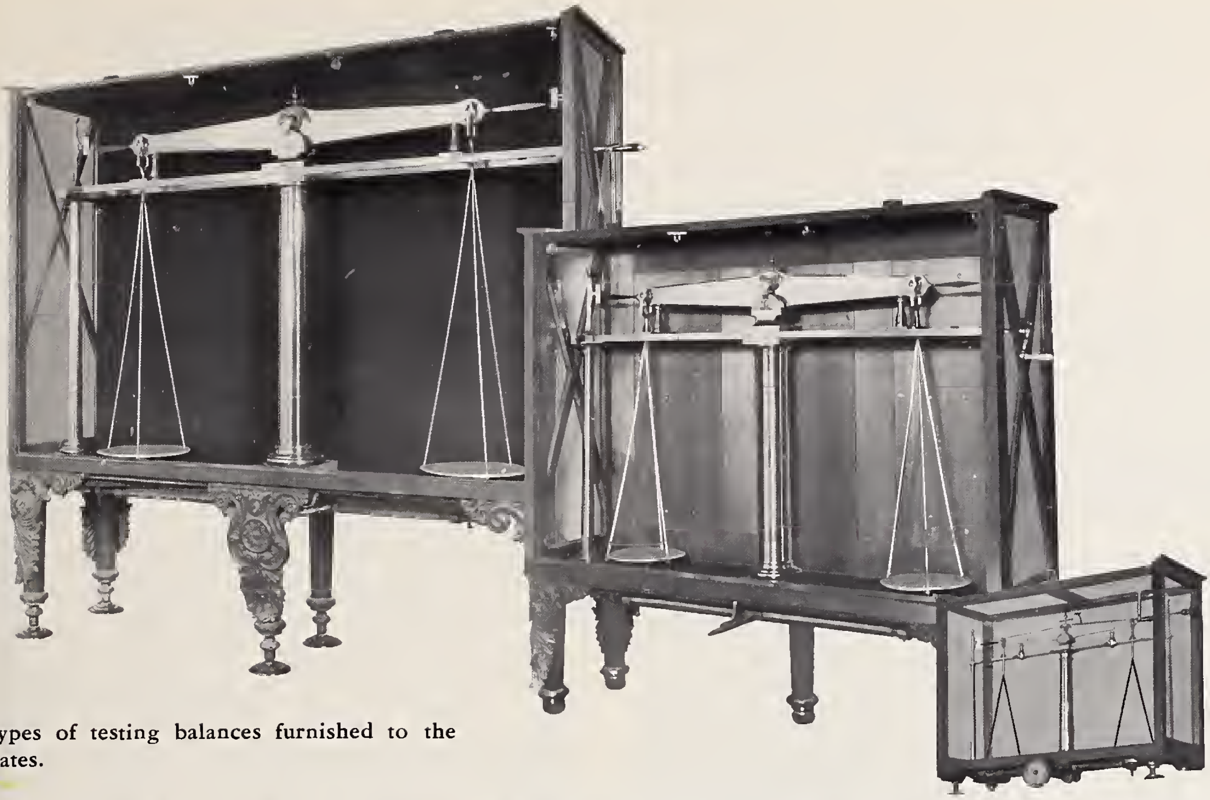
4. Early United States Standards

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-

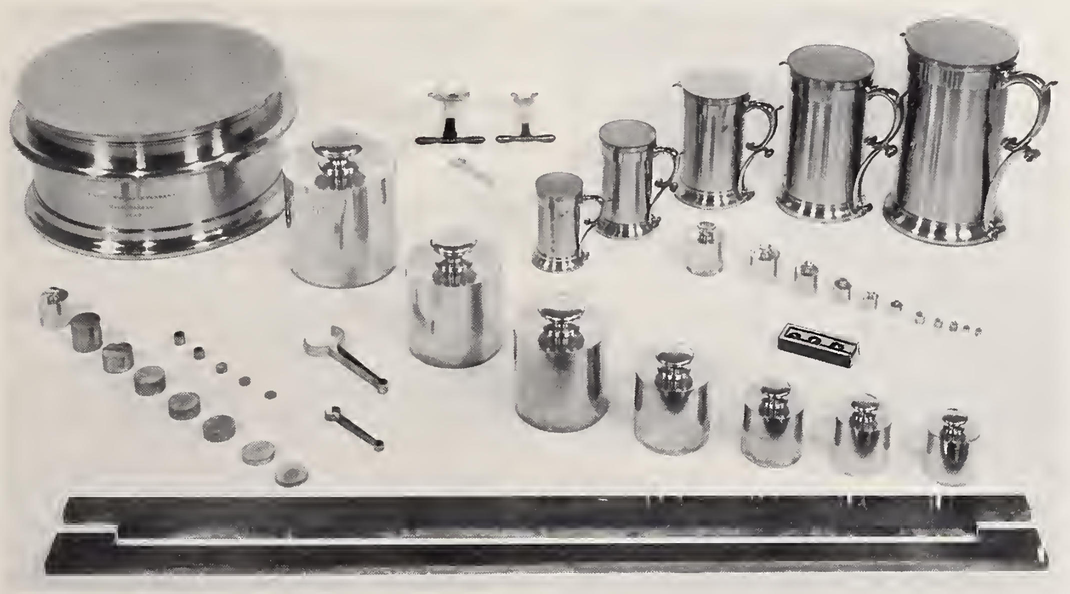
[10] Article I, sec 8, clause 1.



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.

MEASURES OF LENGTH

Metric denominations and values		Equivalents in denominations in use	
myriameter*	10 000 meters	6.2137	miles.
kilometer	1 000 meters	0.62137	mile, or 3,280 feet and 10 inches.
hectometer	100 meters	328	feet and 1 inch.
dekameter	10 meters	393.7	inches.
meter	1 meter	39.37	inches.
decimeter	1/10 of a meter	3.937	inches.
centimeter	1/100 of a meter	0.3937	inch.
millimeter	1/1000 of a meter	0.0394	inch.

MEASURES OF CAPACITY

Metric denominations and values			Equivalents in denominations in use	
Names	Number of liters	Cubic measure	Dry measure	Liquid or wine measure
kiloliter or stere*	1 000	1 cubic meter	1.308 cubic yards	264.17 gallons.
hectoliter	100	1/10 of a cubic meter	2 bushels and 3.35 pecks	26.417 gallons.
dekaliter	10	10 cubic decimeters	9.08 quarts	2.6417 gallons.
liter	1	1 cubic decimeter	0.908 quart	1.0567 quarts.
deciliter	1/10	1/10 of a cubic decimeter	6.1022 cubic inches	0.845 gill.
centiliter	1/100	10 cubic centimeters	0.6102 cubic inch	0.338 fluid ounce.
milliliter	1/1000	1 cubic centimeter	0.061 cubic inch	0.27 fluid dram.

MEASURES OF SURFACE

Metric denominations and values		Equivalents in denominations in use	
hectare	10000 square meters	2.471	acres.
are	100 square meters	119.6	square yards.
centare	1 square meter	1,550	square inches.

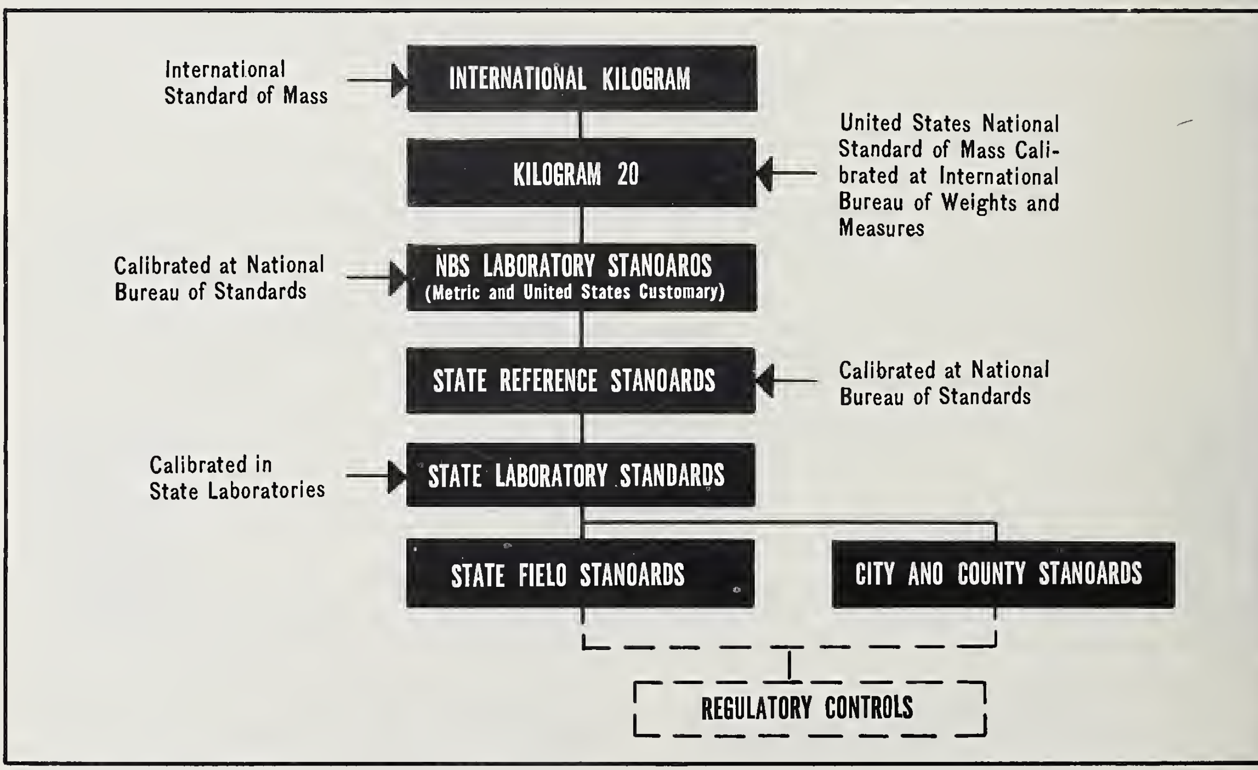
WEIGHTS

Metric denominations and values			Equivalents in denominations in use
Names	Number of grams	Weight of what quantity of water at maximum density	Avoirdupois weight
millier*or tonneau *	1 000 000	1 cubic meter	2204.6 pounds.
quintal*	100 000	1 hectoliter	220.46 pounds.
myriagram*	10 000	10 liters	22.046 pounds.
kilogram or kilo*	1 000	1 liter	2.2046 pounds.
hectogram	100	1 deciliter	3.5274 ounces.
dekagram	10	10 cubic centimeters	0.3527 ounce.
gram	1	1 cubic centimeter	15.432 grains.
decigram	1/10	1/10 of a cubic centimeter	1.5432 grains.
centigram	1/100	10 cubic millimeters	0.1543 grain.
milligram	1/1000	1 cubic millimeter	0.0154 grain.

*Ed. Note: These terms are obsolete.

Metric standards of length, mass, and capacity, furnished to the States under the joint resolution of Congress of July 27, 1866.

In the illustration the liter (litre) and the dekaliter (decalitre) are at the upper left and center, each with a slicker plate in position. The weights are centrally positioned. In the foreground are two meter bars, the upper one a line standard and the lower one an end standard.



Progression of standards.

The Arago kilogram was procured in 1821 by Gallatin while minister of the United States to France and was sent to this country, together with a platinum meter. The certificate of Arago, the celebrated physicist, which accompanied these standards, states that the kilogram differs from the original kilogram of the Archives by less than 1 mg. The weight is a platinum cylinder with flat bases, the edges being slightly rounded. The height and diameter are nearly equal, being approximately 39.5 mm each. There is no stamp or distinguishing mark of any kind, except near the center of one base there is a faint lathe or tool mark of circular form, thus: ⊙. The weight is contained in a square mahogany box, on the cover of which is a circular silver plate bearing the inscription "Kilogramme comparé pour son Poids à l'Etalon Prototype des Archives de France, et verifié par M. Arago. Fortin fecit." (Kilogram compared for its weight with the prototype standard of the Archives of France, and verified by Mr. Arago. Made by Fortin.) No particulars of Arago's comparison with the kilogram of the Archives were furnished, and consequently it is not known what means he used in making his comparison nor whether he reduced his weighings to vacuo. It was not until 1879 that the Arago kilogram was compared with other standards of recognized authority. It is true that it was compared between 1852 and 1873 with two kilograms in the possession of the Office of Weights and Measures, but as both of these weights were of brass and of unknown density, no great reliance could be attached to the results. In 1879, however, it was taken to England and there compared with the British platinum kilogram in the custody of the Standards Office. This comparison indicated that the Arago kilogram was 4.25 mg light, but this result could not be considered conclusive, on account of certain assumptions made in the reduction to vacuo and also in regard to the correction to the British kilogram.

In 1884 the weight was taken from the Standards Office in London, where it had been since 1879, to the International Bureau of Weights and Measures at Paris and there compared with two auxiliary kilograms whose values in terms of the kilogram of the Archives were known with the greatest accuracy. The result obtained from the comparison confirmed that previously obtained from the comparison with the British kilogram, the result giving

$$\text{Arago kilogram} = 1{,}000 \text{ g} - 4.63 \text{ mg.}$$

As the weights supplied to the States were to be made of brass, it was more convenient to compare them with a brass standard, and in order to do this two secondary brass standards were carefully compared between the years 1873–1876 with the Arago kilogram and afterwards used in all the work of adjustment and verification. One of the kilograms, known as the Silbermann kilogram, was presented to the United States by France in 1852, together with a number of other weights and measures. The other kilogram used was one made in the Office of Weights and Measures and was identical in form and material with the kilograms subsequently furnished to the States.

As the unit of capacity in the metric system is defined as the volume of the mass of 1 kilogram of pure water at the temperature of maximum density, the most convenient way to adjust such measures, and in fact all capacity measures, is by weighing the water they contain. The only two material standards that need to be considered, therefore, in connection with the metric weights and measures furnished to the States in accordance with the act of 1866 are the committee meter and the Arago kilogram described above.

By the end of 1880 practically all the States had been supplied with sets of metric weights and measures consisting of the following denominations:

Length measures	One brass line meter. One steel end meter.
Capacity measures	One liter made of brass. One dekaliter made of brass.
Weights	One 10-kilogram made of brass. One kilogram made of brass. One ½-kilogram made of brass. One gram made of brass. One set of small silver weights from 4 decigrams to 1 milligram.

6. International Standards of Weights and Measures

It is necessary at this point to go back a few years and give an account of the establishment of the International Bureau of Weights and Measures, since the present fundamental standards of length and mass for practically the whole civilized world result from the establishment of that institution.

In response to an invitation of the French Government, the following countries sent representatives to a conference held in Paris on August 8, 1870, to consider the advisability of constructing new metric standards: Austria, Colombia, Ecuador, France, Great Britain, Greece, Italy, Norway, Peru, Portugal, Russia, Spain, Switzerland, Turkey, and the United States of America, 15 countries in all. This conference was of short duration, on account of the war then raging between France and Germany.

A second conference was held two years later, at which 26 countries, including the United States, were represented. At this conference it was decided that new meters and new kilograms should be constructed to conform with the original standards of the Archives, and a permanent committee was appointed to carry out this decision. The preparation of the new standards had advanced so far by 1875 that the permanent committee appointed by the conference of 1872 requested the French Government to call a diplomatic conference at Paris to consider whether permanent means and appliances for the final verification of the new meters and kilograms should be provided, or whether the work should be regarded as a temporary operation.

In compliance with this request a conference was held in March 1875, at which 20 countries were represented, the United States as usual being included.

On May 20, 1875, 17 of the 20 countries represented signed a document known as the "Metric Convention" or the "Treaty of the Meter." This provided for the establishment and maintenance of a permanent International Bureau of Weights and Measures to be situated near Paris and to be under the control of an international committee elected by the General Conference on Weights and Measures.

In addition to the original primary work of verifying the new metric standards the International Bureau was charged with certain duties, the following being the most important:

(1) The custody and preservation, when completed, of the international prototypes and auxiliary instruments.

(2) The future periodic comparison of the several national standards with the international prototypes.

(3) The comparison of metric standards with standards of other countries.

The expenses of the bureau were to be defrayed by contributions of the contracting governments, the amount for each country depending upon the population and upon the extent to which the metric system was in use in the particular country.

After ratification by the U.S. Senate and the exchange of ratifications at Paris, the Metric Convention was "proclaimed" by Rutherford B. Hayes, President of the United States, on September 27, 1878.

The twenty countries represented at the diplomatic conference at which the treaty was prepared and signed were Argentina, Austria-Hungary, Belgium, Brazil, Denmark, France, Germany, Great Britain, Greece, Italy, the Netherlands, Peru, Portugal, Russia, Spain, Sweden-Norway, Switzerland, Turkey, the United States of America, and Venezuela. Three of these countries did not sign the convention at that time—Great Britain, Greece, and the Netherlands.

Under the terms of the Convention an International Conference of Weights and Measures was established, to meet once every six years and to comprise official delegates designated by each Power signatory to the Convention. The International Committee elected by this Conference meets every two years.

A Convention amending the 1875 Convention was signed at Sèvres, France, on October 6, 1921; after the customary preliminaries this was proclaimed by President Calvin Coolidge on October 27, 1923. Among other amendments made, the new Convention broadened the scope of the work of the International Bureau, enlarged the International Committee from 14 to 18 members, revised the method of calculating the contributions to be assessed against signatory countries for the support of the Bureau, and modified the procedure for access to the standards vault at the International Bureau.

The number of powers adhering to the Metric Convention—and thus supporting the International Bureau—has increased to 44. Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Cameroon, Canada, Chile, Czechoslovakia, Denmark, Dominican Republic, Egypt, Federal Republic of Germany, Finland, France, German Democratic Republic, Hungary, India, Indonesia, Iran, Ireland, Italy, Japan, Korea, Mexico, The Netherlands, Norway, Pakistan, Poland, Portugal, Rumania, Spain, South Africa, Sweden, Switzerland, Thailand, Turkey, USSR, United Kingdom, USA, Uruguay, Venezuela, Yugoslavia.

The International Committee has had as members, at one time or another, many of the world's leading metrologists. The United States has been represented on the Committee by J. E. Hilgard (1875–1887), B. A. Gould (1887–1896), A. A. Michelson (1897–1904), S. W. Stratton (1905–1931), A. E. Kennelly (1933–1939), E. C. Crittenden (1946–1954), A. V. Astin (1954–1969), L. M. Branscomb (1969–1972) and E. Ambler (1972–).

The International Bureau of Weights and Measures is situated in the town of Sèvres, France, near the Sèvres end of the Park of St. Cloud, which extends between the towns of St. Cloud and Sèvres. The plot of ground was ceded by France to become international territory. The main office building, used also for the library and for the home of the Director, was originally a royal dwelling known as the Pavillon de Breteuil. The present official address of

The International Bureau of Weights and Measures, Sèvres, France.

the bureau is Pavillon de Breteuil, Sèvres (Seine-et-Oise), France.

The construction of the meters and kilograms had been entrusted to a special committee which carried out its tasks meticulously and with great scientific thoughtfulness. These international and national standards were designated as "prototypes," a term that is confusing in the minds of many people. Notwithstanding the dictionary definition of "prototype" as the original, model, or pattern after which something is copied, the term in metrological usage signifies that which is first in status or chief in rank or importance, a usage that dates back at least to 1875. Thus the expression "International Prototype Kilogram" is used to mean the kilogram standard that ranks highest as an international standard, that provides the most authentic value in the world for the kilogram mass, and not necessarily as the pattern for the construction of other kilogram standards. The expression "United States National Prototype Kilograms No. 20 and 4" is used to mean the particular kilogram standards, identified as "No. 20" and "No. 4," respectively, which standards rank highest in this country.

The international and national prototype meter bars, constructed in accordance with the terms of the Convention of the Meter of 1875, are of like design; the cross section is designed to provide maximum rigidity in a bar of reasonably small dimensions and mass, and to reduce to a minimum the effects of any slight bending that may take place when a bar is in normal use. This cross section is a modified X known as the "Tresca section" in honor of the French scientist, Henri Tresca, who proposed it. The overall dimensions of the cross section of the prototype meter bars are 20 x 20 millimeters.

In a bar of Tresca cross section, the upper surface of the central rib lies in the plane of the neutral axis of the bar, the plane in which any variations in the length of the bar that may be caused by slight deformation of the bar are reduced to the practicable minimum.

The international and national prototypes are approximately 1020 millimeters in overall length. As originally constructed (some bars have been regraduated in recent years), near each end of a bar, on the upper surface of the central rib, is a small, elliptical, polished area, and on this area are engraved two groups of parallel lines, the first comprising three transverse lines and the second two longitudinal lines. The central lines of each of the two transverse groups are the essential defining lines of the bar, the auxiliary lines being positioned at one-half millimeter distances on either side. (These auxiliary lines were intended for such purposes as calibrating the micrometer microscopes of length comparators.) The lines of each transverse group are crossed by the lines of a longitudinal group, these latter lines being 0.2 millimeter apart and somewhat more than 1 millimeter in length; the longitudinal lines serve to identify that small portion of each defining line that is to be utilized when the bar is used. Also engraved on each bar is its identifying number.

As for the international and national kilograms, they are in the form of right circular cylinders of equal diameter and height—approximately 39 millimeters—with slightly rounded edges. Engraved on each is its identifying number.

Thirty-one meter bars and 40 kilograms were constructed under the supervision of the International Bureau. The work of construction and calibration was completed by 1889; and in September of that year the first General Conference on Weights and Measures was held in Paris, and this work was approved at this meeting.

The meter and kilogram that agreed most closely with the meter and kilogram of the Archives were declared to be the international meter and the international kilogram. These two standards, with certain other meters and kilograms, were deposited in a subterranean vault under one of the buildings of the International Bureau, where they are only accessible when three independent officials with different keys are present. The other standards were distributed by lot to the various governments contributing to the support of the International Bureau. Those falling to the United States were meters Nos. 21 and 27 and kilograms Nos. 4 and 20.

Meter No. 27 and kilogram No. 20 were brought under seal to this country by George Davidson, of the Coast and Geodetic Survey. On January 2, 1890, the packing cases containing these standards were opened at the White House and the standards were accepted by President Harrison, who certified that they were received in good condition and that he confidently believed that they were the standards referred to in the reports. These reports, relating to the standards in question, had been submitted by B. A. Gould, United States delegate to the International Conference on Weights and Measures, and by Davidson. The other two standards were received the following July and were deposited in the Office of Weights and Measures, where those accepted as national standards by the President had already been taken.[17]

7. The Mendenhall Order

Thomas Corwin Mendenhall, 1841–1924.

On April 5, 1893, T. C. Mendenhall, then Superintendent of Weights and Measures, with the approval of the Secretary of the Treasury, decided that the international meter and kilogram would in the future be regarded as the fundamental standards of length and mass in the United States, both for metric and customary weights and measures. This decision, which has come to be known as the "Mendenhall Order," was first published as Bulletin No. 26 of the Coast and Geodetic Survey, approved for publication April 5, 1893, under the title, "Fundamental Standards of Length and Mass"; it was republished in 1894 under the same title, as appendix No. 6—Report for 1893 of the Coast and Geodetic Survey, "to give it a more permanent form." In appendix No. 6 there was included as an addendum to the text of Bulletin No. 26 a section headed "Tables for Converting Customary and Metric Weights and Measures," comprising some text, five customary-to-metric conversion tables, and five metric-to-customary conversion tables.

As a matter of interest and record, the full text of appendix No. 6 of the Report for 1893 of the Coast and Geodetic Survey, with the exception of an editorial footnote and the ten conversion tables, is reproduced as appendix 3 of this publication.

The Mendenhall Order initiated a departure from the previous policy of attempting to maintain our standards of length and mass to be identical with those of Great Britain, and thereafter there was a small difference between the British and the United States yards, a difference which may have been negligible in 1893 but which became of real importance as the British Imperial Yard bar gradually changed in length and as the requirements for greater accuracy in measurements increased.

As has been seen, when the United States yard was first adopted upon Hassler's recommendation in 1832, it was defined as a particular interval on the Troughton bar, through which it was related to the British yard standard. The intention was to fix the United States yard as equal to the British yard.

When the "Imperial" system of weights and measures was established by the British in 1824, the Imperial Yard was defined in terms of a specific yard standard and a particular bar was legalized as the Imperial standard. In 1834, that bar was so damaged in the burning of the Houses of Parliament that replacement was necessary; a new bar was constructed, and in 1855 this bar was legalized as the new Imperial Standard Yard. In the course of the years this bar proved to be insufficiently stable in length and was found to be shortening by measurable amounts.

[17] Upon the establishment of the Bureau of Standards on July 1, 1901, all standards and other property in possession of the Office of Weights and Measures passed under the control of the Bureau.

For a time, efforts were made by United States authorities to maintain equivalence between the United States and British yards. Such efforts were abandoned, however, in 1893, when the Mendenhall Order (see appendix 3, p. 26) defined the United States yard in terms of the International Prototype Meter.

The difference between the United States and the British yards, prior to the 1959 actions of both governments in recognizing the new International Yard (see appendix 5, p. 28), reached a maximum value in the order of 0.000 13 inch, the United States yard being the longer.

The case of the pound was slightly different as will be seen from the record of the values assigned to it with respect to the kilogram.

The United States law of 1866 that made the use of the metric system permissive, carries the relation, 1 kilogram=2.2046 avoirdupois pounds, an equation now believed to have been intended as sufficiently accurate for commercial purposes but not as a precise definition of the relationship between basic units. This value resulted from a rounding off of the results of an 1844 comparison made in England between the British pound and the Kilogram of the Archives which gave the relation, 1 pound=0.453 592 65 kilogram; this relation was used in Great Britain and in the United States for years. Expressed reciprocally, this relation becomes, approximately, 1 kilogram= 2.204 621 61 pounds.

In the Coast and Geodetic Survey Report for 1893 that contained the Mendenhall Order, (see appendix 3, p. 26), the kilogram-avoirdupois pound relationships are variously stated as follows:

1 pound avoirdupois $= \frac{1}{2.2046}$ kg

1 pound avoirdupois $= \frac{1}{2.20462}$ kg

2.204 622 34 pounds avoirdupois =1 kilogramme

1 avoirdupois pound =453.592 427 7 grammes

A comparison made in 1883 between the British Imperial Standard Pound and the International Prototype Kilogram resulted in the relation 1 Imperial Pound=0.453 592 427 7 Kilogram; this relation was accepted in both Great Britain and the United States, but uniformity between the two countries ended in 1889 when Great Britain officially adopted a rounded-off value, making the relation, 1 Imperial Pound= 0.453 592 43 Kilogram. From its founding in 1901 until July 1, 1959, the National Bureau of Standards recognized and used the relation 1 pound avoirdupois=0.453 592 427 7 kilogram.

This uncertainty as to the precise values of the units of length and mass in common use, the yard and the pound respectively, was caused by inadequacies of the standards representing them. The bronze yard No. 11, which was an exact copy of the British imperial yard both in form and material, had shown changes when compared with the imperial yard in 1876 and 1888 which could not reasonably be said to be entirely due to changes in No. 11. Suspicion as to the constancy of the length of the British standard was therefore aroused. Neither the troy pound of the mint nor the copies of the imperial yard in the possession of the Office of Weights and Measures were satisfactory standards. The mint pound is made in two pieces, the knob being screwed into the body; hence its density can not be determined by weighing in water on account of danger of leakage. Moreover, it is made of brass not plated, and therefore liable to alteration by oxidation.

On the other hand, the new meters and kilograms represented the most advanced ideas of standards, and it therefore seemed that greater stability in our weights and measures as well as higher accuracy would be secured by accepting the international meter and kilogram as fundamental standards.

Time proved the wisdom of this action, and therefore when the National Bureau of Standards was established in July 1901, it fully accepted the decision made by the Office of Weights and Measures in 1893 to adopt the meter and kilogram as fundamental standards.

The National Bureau of Standards was established in response to the requests of scientists, technologists, and industrialists that a governmental agency be founded to develop standards, carry out researches basic to standards, and calibrate standards and devices. The Office of Weights and Measures had carried out some of this work in its limited field, and the increasing use of electricity was making the need of a central standardizing authority rather critical. Similar needs were also felt in other fields of science and industry.

Institutions of the type envisioned had already been formed in Great Britain and Germany and the Office of Weights and Measures was deemed to be a suitable nucleus on which to build in this country. Fortunately, Congress was favorably impressed with the idea and on March 3, 1901 it passed an act providing that "The Office of Standard Weights and Measures shall hereafter be known as the National Bureau of Standards" and setting forth the functions of the new Bureau. These functions were considerably expanded in an amendment passed in 1950.

Executive Mansion.

Be it known: That on this second day of January A.D. one thousand eight hundred and ninety in the City of Washington there were exhibited before me, Benjamin Harrison, President of the United States, by T.C. Mendenhall, Superintendent of the United States Coast and Geodetic Survey two packing boxes described as follows:

One box bearing the stencil number 27 and sealed twice with red wax bearing the impress of a crest over the Gothic letter G.

One small hinged box bearing the stencil number 20 and the letter A and sealed twice with red wax bearing the impress of a crest over the Gothic letter G as before described, and with two black seals with the Gothic letters W.R.

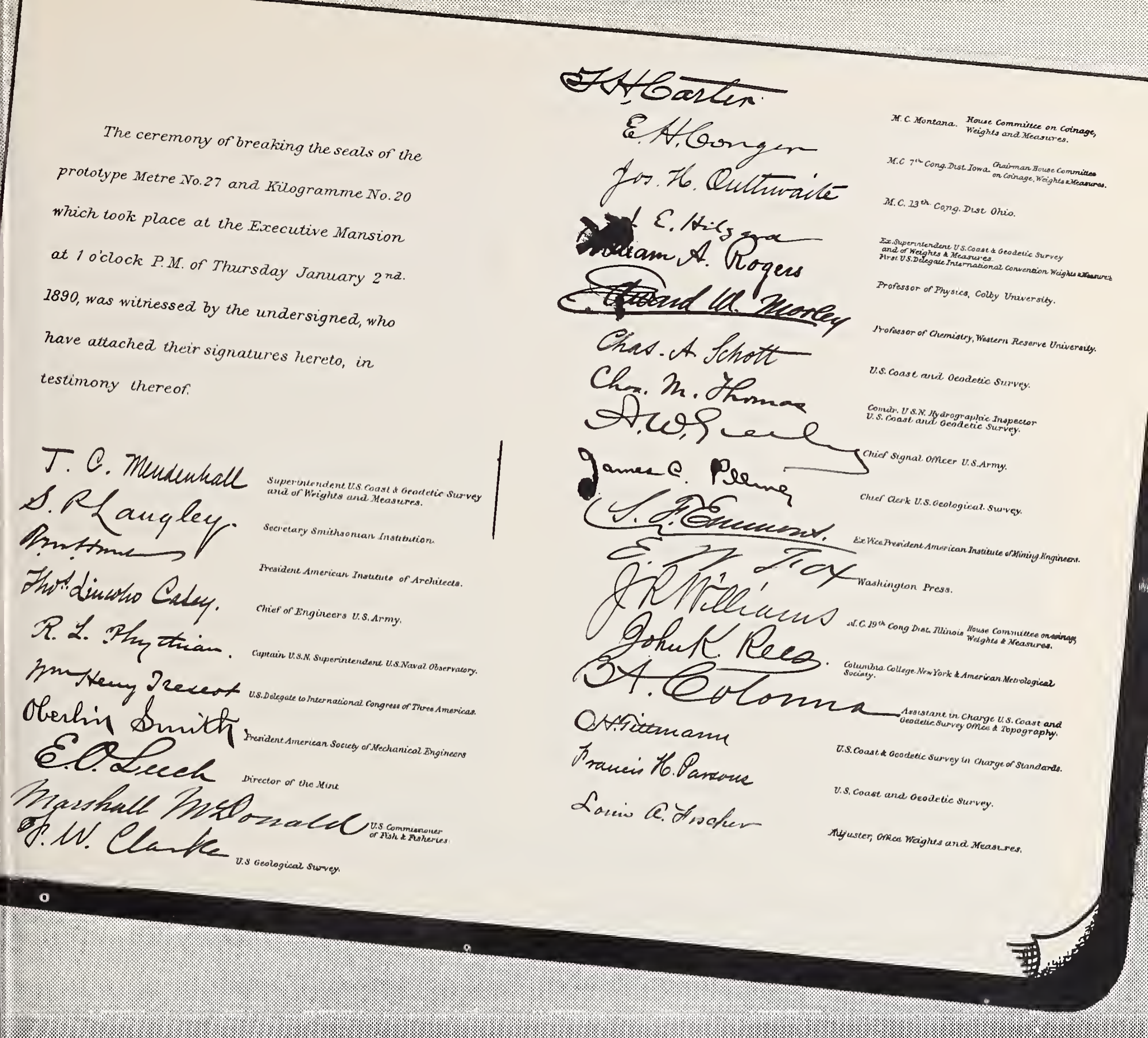
That the impression of the red wax seals aforesaid was recognized as that of the private seal of Dr. Benjamin Apthorp Gould, United States Delegate to the International Conference on Weights and Measures convened at Paris September 24th 1889, that there was also exhibited a report by said B.A. Gould to the Secretary of State reciting that he received and accepted on behalf of the United States a prototype Metre numbered 27 together with another one numbered 21 metre bar of the alloy of 1874 numbered 12, together with two prototype Kilogrammes, one numbered 4, and one numbered 20 with their accessories, excepting thermometers: and that he enclosed said prototype Metre No. 27 and said prototype Kilogramme No. 20 with its accessories in their inner cases and these in their turn in boxes marked and thereafter sealed by him as above described and that said boxes were delivered by him to Mr. Whitelaw Reid, United States Minister at Paris, and there was also exhibited a report by George Davidson, Assistant United States Coast and Geodetic Survey, affirming that these boxes were received by him from the United States Minister at Paris on October 27th 1889 as being the boxes supposed to contain the National Prototype Metre No. 27, and the National Propotype Kilogramme No. 20 with its accessories.

That the Superintendent of the Coast and Geodetic Survey did affirm that these boxes were received by him from the said George Davidson on the 27th day of November 1889 at the Office of the Coast and Geodetic Survey in Washington, D.C. and that they have remained in his possession, sealed and with their contents undisturbed in every particular from the date of their delivery aforesaid until thus exhibited.

That the aforesaid boxes being thereupon opened in my presence were found to contain the inner cases as described in the aforementioned report of Dr. B.A. Gould and these inner cases being opened were found to contain a Metre bar numbered 27 and a Kilogramme weight No. 20 in good preservation and apparently in every particular in the same state as when first enclosed therein, and which I therefore confidently believe to be the identical Standards referred to in the aforesaid reports.

Benj Harrison

By the President
James G Blaine
Secretary of State
January 2/1890 -
William Windom
Secretary of the Treasury.



The ceremony of breaking the seals of the prototype Metre No. 27 and Kilogramme No. 20 which took place at the Executive Mansion at 1 o'clock P.M. of Thursday January 2nd. 1890, was witnessed by the undersigned, who have attached their signatures hereto, in testimony thereof.

T. C. Mendenhall	Superintendent U.S. Coast & Geodetic Survey and of Weights and Measures.
S. P. Langley	Secretary Smithsonian Institution.
R. M. Hunt	President American Institute of Architects.
Thos. Lincoln Casey	Chief of Engineers U.S. Army.
R. L. Phythian	Captain U.S.N. Superintendent U.S. Naval Observatory.
Wm. Henry Trescot	U.S. Delegate to International Congress of Three Americas.
Oberlin Smith	President American Society of Mechanical Engineers
E. O. Leech	Director of the Mint
Marshall McDonald	U.S. Commissioner of Fish & Fisheries
F. W. Clarke	U.S. Geological Survey.
J. H. Carter	M.C. Montana. House Committee on Coinage, Weights and Measures.
E. H. Conger	M.C. 7th Cong. Dist. Iowa. Chairman House Committee on Coinage, Weights & Measures.
Jos. H. Outhwaite	M.C. 13th Cong. Dist. Ohio.
J. E. Hilgard	Ex Superintendent U.S. Coast & Geodetic Survey and of Weights & Measures. First U.S. Delegate International Convention Weights & Measures
William A. Rogers	Professor of Physics, Colby University.
Edward W. Morley	Professor of Chemistry, Western Reserve University.
Chas. A. Schott	U.S. Coast and Geodetic Survey.
Chas. M. Thomas	Comdr. U.S.N. Hydrographic Inspector U.S. Coast and Geodetic Survey.
A. W. Greely	Chief Signal Officer U.S. Army.
James C. Pilling	Chief Clerk U.S. Geological Survey.
S. F. Emmons	Ex Vice President American Institute of Mining Engineers.
E. W. Fox	Washington Press.
J. R. Williams	M.C. 19th Cong Dist. Illinois House Committee on Coinage, Weights & Measures.
John K. Rees	Columbia College New York & American Meteorological Society.
B. A. Colonna	Assistant in Charge U.S. Coast and Geodetic Survey Office & Topography.
O. H. Tittmann	U.S. Coast & Geodetic Survey in Charge of Standards.
Francis H. Parsons	U.S. Coast and Geodetic Survey.
Louis A. Fischer	Adjuster, Office Weights and Measures.

Certificate in relation to the ceremony of breaking the seals of Meter No. 27 and Kilogram No. 20.

The original of this certificate is preserved in the standards vault of the National Bureau of Standards. It will be observed that the last signature on this certificate is that of Louis A. Fischer, who signed as Adjuster, Office of Weights and Measures.

Certificate in relation to the receipt of the national prototype metric standards of length and mass.

The original of this certificate is preserved in the standards vault of the National Bureau of Standards.

in expanding the work in weights and measures into a national standards bureau, the work in the field of weights and measures had more opportunities for growth. Mr. Louis A. Fischer, Chief of the Division of Weights and Measures from the organization of the National Bureau of Standards in 1901 until his death in 1921, probably was the first man in the United States to undertake the promotion of weights and measures supervision on a national basis. In 1902, Mr. Fischer directed scattered inspections of weighing and measuring devices and transactions involving quantities in several of the larger cities in the State of New York. The purpose of these visits was to determine what amount of protection the buying public was receiving against short weight and short measure in purchases. As a result of this investigation, as well as the increasing number of complaints being received in Washington, staff members of the National Bureau of Standards decided in 1904 to call a meeting of weights and measures officials and other officers of the State governments to discuss ways and means of affording to the public adequate supervision over weights and measures in everyday transactions.

This meeting was held in Washington in 1905, and, although invitations went to all States, the meeting was attended by only eleven persons, representing eight States, the District of Columbia, and the National Bureau of Standards. As it turned out, this was the first National Conference on Weights and Measures, and was the inauguration of meetings that have been held annually with exceptions due to war or other national emergency. Interest, attendance, and participation in the Conferences, as well as the influence of the Conference, have increased steadily. The registered attendance at the 47th meeting, held in Washington during June 1962, was 420. Out of the National Conference on Weights and Measures has come the basis for uniformity of weights and measures law and enforcement activities.

The delegates to the first Conference and to all subsequent meetings have had as their principal aim the application of uniform and satisfactory standards of measurement to everyday commercial transactions.

The need for uniformity of State weights and measures legislation was one of the principal reasons for the first national meeting of weights and measures officials and was considered at that time. As the result of a resolution of the second meeting, a Model State Law on Weights and Measures was composed. In the year 1911, after detailed and extensive discussions, the Sixth National Conference adopted, with a few minor changes and additions, a Model Law that had been drafted at the National Bureau of Standards. Since that time this document has been subject to continued study and revisions, additions, and deletions have been made as needed. Thus was made available to the States a model upon which individual State legislation could be patterned.

Supplemental to the Model Law are codes of specifications, tolerances, and regulations for commercial weighing and measuring devices which receive especially critical attention, because many of the States officially adopt these requirements by reference or citation with cumulative provision, resulting in their being given legal status upon adoption by the Conference and publication by the National Bureau of Standards. Manufacturers of equipment are guided in their engineering designs, and essentially all weights and measures inspectors aline their procedures, according to the Conference codes.

8. Refinement of Values for the Yard and Pound

When the National Bureau of Standards began its work in 1901 the principal units of weights and measures in the U.S. customary system were defined as follows:

$$1 \text{ yard} = \frac{3600}{3937} \text{ meter}$$

1 pound = 0.453 592 427 7 kg
1 gallon = 231 cubic inches
1 bushel = 2 150.42 cubic inches

These definitions remained unchanged for 58 years, and the last two are still the official values.

The precision requirements in length measurements increased greatly during these years, and the differences between the U.S. inch and the British inch became especially important in gage-block standardization. The difference between the U.S. pound and the British pound was also rather annoying. As a result of many years of preliminary discussion, the directors of the national standards laboratories of Australia, Canada, New Zealand, South Africa, the United Kingdom, and the United States entered into agreement, effective July 1, 1959, whereby uniformity was established for use in the scientific and technical fields. The equivalents 1 yard = 0.9144 meter (whence 1 inch = 25.4 millimeters) and 1 avoirdupois pound = 0.453 592 37 kilogram (whence 1 grain = 0.064 798 91 gram and 1 avoirdupois ounce = 28.349 523 125 grams) were adopted for each of these national laboratories. It will be noted from the U.S. announcement (see appendix 5, p. 28) that these same equivalents will also be used in this country in trade.

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

$$1 \text{ U.S. yard} = 0.914\ 399\ 80 \text{ meter}$$

or

$$1 \text{ meter} = 39.370\ 09 \text{ U.S. inches}$$

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.

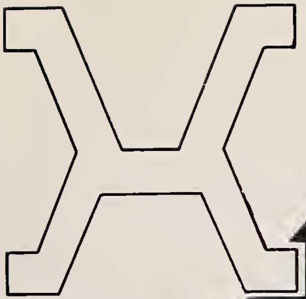
The left, or zero, end of the bar is illustrated.

Low Moor Iron Yard No. 57.

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

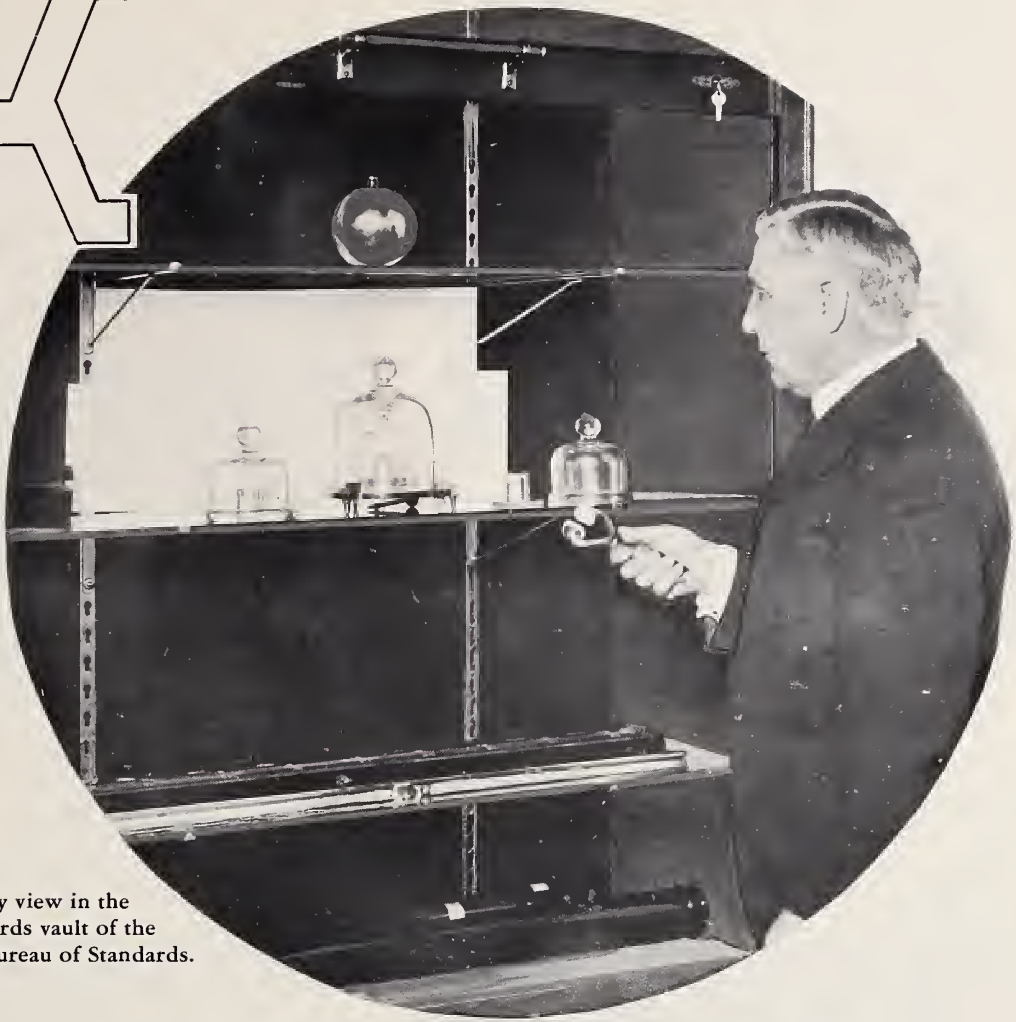
The grave.

"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 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 procured 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.

Public Law 93–380, "the Education Amendments of 1974," enacted August 21, 1974 includes a Section (403.(a)(1)) which states that "It is the policy of the United States to encourage educational agencies and institutions to prepare students to use the metric system of measurement with ease and facility as a part of the regular education program." The Office of Education, Department of Health, Education, and Welfare is responsible for implementing this policy.

Public Law 94–168, the "Metric Conversion Act of 1975," enacted December 23, 1975 declares that "the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States and to establish a United States Metric Board to coordinate the voluntary conversion to the metric system." PL 94–168 thus recognizes that increasing use of the metric system as of 1975 is an actuality in the United States and places responsibility for coordinating this increasing use in a U.S. Metric Board appointed by the President.

Both PL 93–380 and PL 94–168 provide that "metric system of measurement" means the International System of Units (commonly referred to as SI) as established by the General Conference on Weights and Measures in 1960 and as interpreted or modified for the United States by the Secretary of Commerce. On behalf of the Secretary of Commerce the National Bureau of Standards has implemented this responsibility by having published a Federal Register Notice dated June 19, 1975 which is reproduced as Appendix 7.

Two Federal Register Notices related to our customary system of weights and measures have been published since 1963.

A Federal Register Notice of July 27, 1968 (see appendix 8), issued in response to a request of the House Committee on Science and Astronautics lists the weights and measures used in normal commerce and relates them to the standards developed in accordance with existing law.

A Federal Register Notice of February 3, 1975 (see appendix 9) supplements the July 27, 1968, Notice; it explains the difference between the survey mile and international mile on the one hand and the survey foot and the international foot on the other. It is of interest to note that the international foot and mile are exactly 0.999 998 as long as the survey foot and mile, respectively. Although the term statute mile (5280 feet) can be interpreted to be either the survey mile or the international mile, in the United States, the U.S. statute mile remains the same as the U.S. survey mile.

Starting in 1965 with the enactment of Public Law 89–164 the Congress, over a ten-year period, appropriated a total of 1.8 million dollars to the National Bureau of Standards for the specific purpose of supplying standards of weight and measure to the States. These funds have been used to supply sets of customary and metric standards of weight (mass), length, and volume, as well as precision balances to practically all of the 50 States and also to the District of Columbia, the Commonwealth of Puerto Rico, and the Virgin Islands.

Appendix 1. Bibliography

The first of the following principal sources consulted in the preparation of this publication was used very extensively. It is therefore placed at the head of the list; the others are listed alphabetically.

FISCHER, Louis A., History of the Standard Weights and Measures of the United States, NBS Miscellaneous Publication 64;

BACHE, Alexander D., Report on the Construction and Distribution of Weights and Measures, S. Ex. Doc. No. 27, 34th Congress, 3d Session;

BIGOURDAN, Guillaume, Le Système Métrique des Poids et Mesures;

CHANEY, Henry J., Our Weights and Measures;

CHISHOLM, Henry W., On the Science of Weighing and Measuring and Standards of Measure and Weight;

GUILLAUME, Charles E., La Création du Bureau International des Poids et Mesures et son Oeuvre;

HASSLER, Ferdinand R., Comparison of Weights and Measures, H. R. Doc. 299, 22d Congress, 1st Session;

BOARD OF TRADE, GREAT BRITAIN, Reports on their Proceedings and Business under the Weights and Measures Act 1878;

COMITÉ INTERNATIONAL DES POIDS ET MESURES, Procés Verbaux des Séances;

CONFÉRENCES GÉNÉRALES DES POIDS ET MESURES, Comptes Rendus des Séances.

Appendix 2. Report on the Troy Pound of the Mint

Reproduced below is the text of an appendix to the report of the Committee of the Franklin Institute on Weights and Measures comprising a report of Dr. Samuel Moore, Director of the United States Mint, dated October 1, 1833, dealing with the original troy pound of the Mint. This report was printed in the Journal of the Franklin Institute of the State of Pennsylvania in the issue of May 1834 (Vol. XIII, New Series, No. 5), p. 302–3.

APPENDIX TO THE REPORT OF THE COMMITTEE OF THE FRANKLIN INSTITUTE ON WEIGHTS AND MEASURES

Report of Dr. Samuel Moore on the authentication of the Troy Pound in possession of the Mint of the United States

To the committee of the Franklin Institute charged with the subject of Weights and Measures

Mint of the United States, October 1, 1833.

The standard troy pound of the mint is a copy, executed with great care, of the British parliamentary troy pound of 1758, recognised and designated in the year 1824 as the imperial troy pound of Great Britain. It was procured at my request, in 1827, through the attention and influence of Mr. Gallatin, Minister of the United States at London. By the friendly offices of Mr. Davies Gilbert, Vice President of the Royal Society, the standard troy pound in the care of the Clerk of the House of Commons, was, on the application of Mr. Gallatin to the Speaker of the House, committed to the charge of Capt. Kater, for the purpose of effecting at his own house an adjustment of the copy to the original.

The standard weight is of brass, the original being of that material. It was made by Mr. Bate, who had constructed all the standard British weights, and the comparison with the original was made by a very delicate beam constructed by Robinson, the same artist who had constructed the beam with which Capt. Kater compared the standard weights above mentioned with the original standard troy pound.

The weight was enclosed in a neat casket carefully enveloped under seal of the American legation at London, and committed by Mr. Gallatin himself to the hands of Mr. Cucheval, a public messenger, bearing despatches from the legation to the United States, by whom it was delivered into my hands, accompanied by a packet containing ample certificates from Capt. Kater and Mr. Gallatin, testifying to the accuracy of the weight in question.

The casket and accompanying package were retained under seal, waiting the return of Mr. Adams, President of the U.S., from his family residence to Washington, in order that the seal of Mr. Gallatin, and the various facts of chief moment, in regard to the authentication of the weight, might be verified, on his authority. They were accordingly opened in the presence of Mr. Adams, in Philadelphia, on the 12th of October, 1827, and his full certificate in regard to the seal, which he readily recognised, and to the circumstances generally, giving assurance of the fidelity of the whole transaction, and the consequent accuracy of the weight, has been added to the vouchers in the case; he declaring, in conclusion, his entire belief, that the brass weight then exhibited was the identical copy of the imperial standard troy pound of Great Britain, intended and referred to in the aforesaid certificates.

The above facts having been communicated to Congress through the committee on the mint, the troy pound thus certified was specifically declared by law to be "the standard troy pound of the mint of the United States, according to which the coinage thereof shall be regulated." See section 2nd of the act of May 19, 1827, respecting the mint, a copy of which is hereto annexed.

This is the specific pound weight, assumed as the standard unit of the system of weights reported to the Senate of the United States, under a resolution of that body of 29th May, 1830—see a communication from Mr. Ingham, Secretary of the Treasury, made to the Senate March 3d, 1831; also the report of Mr. Hassler on the subject, 27th January, 1832, pages 10 and 25; and a communication to the Senate from Mr. M'Lane, Secretary of the Treasury, accompanying this report, dated 20th June, 1832. It has been constantly in my possession, and is preserved with the utmost care.

Very respectfully, gentlemen,
Your obedient servant,

Samuel Moore,
Director United States Mint.

Appendix 3. The Mendenhall Order of April 5, 1893

This order was published as appendix 6 of the Report for 1893 of the Coast and Geodetic Survey.

FUNDAMENTAL STANDARDS OF LENGTH AND MASS

While the Constitution of the United States authorizes Congress to "fix the standard of weights and measures," this power has never been definitely exercised, and but little legislation has been enacted upon the subject. Washington regarded the matter of sufficient importance to justify a special reference to it in his first annual message to Congress (January, 1790), and Jefferson, while Secretary of State, prepared a report, at the request of the House of Representatives, in which he proposed (July, 1790) "to reduce every branch to the decimal ratio already established for coins, and thus bring the calculation of the principal affairs of life within the arithmetic of every man who can multiply and divide." The consideration of the subject being again urged by Washington, a committee of Congress reported in favor of Jefferson's plan, but no legislation followed. In the meantime the executive branch of the Government found it necessary to procure standards for use in the collection of revenue and other operations in which weights and measures were required, and the Troughton 82-inch brass scale was obtained for the Coast and Geodetic Survey in 1814, a platinum kilogramme and metre, by Gallatin, in 1821, and a troy pound from London in 1827, also by Gallatin. In 1828 the latter was, by act of Congress, made the standard of mass for the Mint of the United States, and, although totally unfit for such purpose, it has since remained the standard for coinage purposes.

In 1830 the Secretary of the Treasury was directed to cause a comparison to be made of the standards of weight and measure used at the principal custom-houses, as a result of which large discrepancies were disclosed in the weights and measures in use. The Treasury Department, being obliged to execute the constitutional provision that all duties, imposts, and excises shall be uniform throughout the United States, adopted the Troughton scale as the standard of length; the avoirdupois pound, to be derived from the troy pound of the Mint, as the unit of mass. At the same time the Department adopted the wine gallon of 231 cubic inches for liquid measure and the Winchester bushel of 2150.42 cubic inches for dry measure. In 1836 the Secretary of the Treasury was authorized to cause a complete set of all weights and measures adopted as standards by the Department for the use of custom-houses and for other purposes to be delivered to the governor of each State in the Union for the use of the States, respectively, the object being to encourage uniformity of weights and measures throughout the Union. At this time several States had adopted standards differing from those used in the Treasury Department, but after a time these were rejected, and finally nearly all the States formally adopted, by act of legislature, the standards which had been put in their hands by the National Government. Thus a good degree of uniformity was secured, although Congress had not adopted a standard of mass or of length, other than for coinage purposes, as already described.

The next and in many respects the most important legislation upon the subject was the act of July 28, 1866, making the use of the metric system lawful throughout the United States and defining the weights and measures in common use in terms of the units of this system. This was the first *general* legislation upon the subject, and the metric system was thus the first, and thus far the only, system made generally legal throughout the country.

In 1875 an international metric convention was agreed upon by seventeen Governments, including the United States, at which it was undertaken to establish and maintain at common expense a permanent international bureau of weights and measures, the first object of which should be the preparation of a new international standard metre and a new international standard kilogramme, copies of which should be made for distribution among the contributing Governments. Since the organization of the Bureau, the United States has regularly contributed to its support, and in 1889 the copies of the new international prototypes were ready for distribution. This was effected by lot, and the United States received metres Nos. 21 and 27 and kilogrammes Nos. 4 and 20. The metres and kilogrammes are made from the same material, which is an alloy of platinum with 10 per cent of iridium.

On January 2, 1890, the seals which had been placed on metre No. 27 and kilogramme No. 20 at the International Bureau of Weights and Measures, near Paris, were broken in the Cabinet room of the Executive Mansion by the President of the United States in the presence of the Secretary of State and the Secretary of the Treasury, together with a number of invited guests. They were thus adopted as the national prototype metre and kilogramme.

The Troughton scale, which in the early part of the century had been tentatively adopted as a standard of length, has long been recognized as quite unsuitable for such use, owing to its faulty construction and the inferiority of its graduation. For many years, in standardizing length measures, recourse to copies of the imperial yard of Great Britain had been necessary, and to the copies of the metre of the archives in the office of weights and measures. The standard of mass originally selected was likewise unfit for use for similar reasons, and had been practically ignored.

The recent receipt of the very accurate copies of the International Metric Standards, which are constructed in accord with the most advanced conceptions of modern metrology, enables comparisons to be made directly with those standards, as the equations of the national prototypes are accurately known. It has seemed, therefore, that greater stability in weights and measures, as well as much higher accuracy in their comparison, can be secured by accepting the international prototypes as the fundamental standards of length and mass. It was doubtless the intention of Congress that this should be done when the international metric convention was entered into in 1875; otherwise there would be nothing gained from the annual contributions to its support which the Government has constantly made. Such action will also have the great advantage of putting us in direct relation in our weights and measures with all civilized nations, most of which have adopted the metric system for exclusive use. The practical effect upon our customary weights and measures is, of course, nothing. The most careful study of the relation of the yard and the metre has failed thus far to show that the relation as defined by Congress in the act of 1866 is in error. The pound as there defined, in its relation to the kilogramme, differs from the imperial pound of Great Britain by not more than one part in one hundred thousand, an error, if it be so called, which utterly vanishes in comparison with the allowances in all ordinary transactions. Only the most refined scientific research will demand a closer approximation, and in scientific work the kilogramme itself is now universally used, both in this country and in England.*

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*NOTE.—Reference to the act of 1866 results in the establishment of the following:

Equations.

$$1 \text{ yard} = \frac{3600}{3937} \text{metre.}$$

$$1 \text{ pound avoirdupois} = \frac{1}{2 \cdot 2046} \text{kg.}$$

A more precise value of the English pound avoirdupois is $\frac{1}{2 \cdot 20462}$ kg., differing from the above by about one part in one hundred thousand, but the equation established by law is sufficiently accurate for all ordinary conversions.

As already stated, in work of high precision the kilogramme is now all but universally used and no conversion is required.

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. Indeed, this course has been practically forced upon this Office for several years, but it is considered desirable to make this formal announcement for the information of all interested in the science of metrology or in measurements of precision.

T. C. Mendenhall,
Superintendent of Standard Weights and Measures.

Approved:
J. G. Carlisle,
Secretary of the Treasury.
April 5, 1893.

[United States Coast and Geodetic Survey.—Office of Standard Weights and Measures—T. C. Mendenhall, Superintendent.]

TABLES FOR CONVERTING CUSTOMARY AND METRIC WEIGHTS AND MEASURES.

Office of Standard Weights and Measures,
Washington, D.C., March 21, 1894.

The yard in use in the United States is equal to $\frac{3600}{3937}$ of the metre.

The troy pound of the mint is the United States standard weight for coinage. It is of brass of unknown density, and therefore not suitable for a standard of mass. It was derived from the British standard troy pound of 1758 by direct comparison. The British avoirdupois pound was also derived from the latter and contains 7,000 grains troy. The grain troy is therefore the same as the grain avoirdupois, and the pound avoirdupois in use in the United States is equal to the British pound.

2·20462234 pounds avoirdupois = 1 kilogramme.

In Great Britain the legal metric equivalent of the imperial gallon is 4·54346 litres, and of the imperial bushel 36·3477 litres.

The length of a nautical mile, as given below, is that adopted by the United States Coast Survey many years ago, and defined as the length of a minute of arc of a great circle of a sphere whose surface is equal to the surface of the earth (the Clarke spheroid of 1866).

1 foot	=	0·304801 metre, 9·4840158 log.
1 fathom	=	1·829 metres.
1 Gunter's chain	=	20·1168 metres.
1 square statute mile	=	259·000 hectares.
1 nautical mile	=	1853·25 metres.
1 avoirdupois pound	=	453·5924277 grammes.
15432·35639 grains	=	1 kilogramme.

* * * * *

By the concurrent action of the principal Governments of the world, an International Bureau of Weights and Measures has been established near Paris. Under the direction of the International Committee, two ingots were cast of pure platinum-iridium in the proportion of 9 parts of the former to 1 of the latter metal. From one of these a certain number of kilogrammes were prepared; from the other a definite number of metre bars. These standards of weight and length were intercompared without preference, and certain ones were selected as international prototype standards. The others were distributed by lot, in September, 1889, to the different Governments, and are called national prototype standards. Those apportioned to the United States were received in 1890 and are in the keeping of this office.

The metric system was legalized in the United States in 1866.

The International Standard Metre is derived from the Metre des Archives, and its length is defined by the distance between two lines at 0° centigrade on a platinum-iridium bar deposited at the International Bureau of Weights and Measures.

The International Standard Kilogramme is a mass of platinum-iridium deposited at the same place, and its weight in vacuo is the same as that of the Kilogramme des Archives.

The litre is equal to a cubic decimetre, and it is measured by the quantity of distilled water which, at its maximum density, will counterpoise the standard kilogramme in a vacuum, the volume of such a quantity of water being, as nearly as has been ascertained, equal to a cubic decimetre.

Appendix 4. The International Nautical Mile

The following announcement is quoted from the National Bureau of Standards Technical News Bulletin of August 1954.

Adoption of International Nautical Mile

Beginning on July 1, 1954, the National Bureau of Standards will use the International Nautical Mile in lieu of the U.S. Nautical Mile. This decision, replacing the U.S. Nautical Mile of 1,853.248 meters (6,080.20 feet) by the International Nautical Mile of 1,852 meters (6,076.10333 . . . feet), confirms an official agreement between the Secretary of Commerce and the Secretary of Defense to use the International Nautical Mile within their respective departments.

The use of a mile derived from the length of a degree of the earth's meridian is very old. It is believed that the Chaldean astronomers determined the length of such a unit. Miles of this sort have been variously called meridian miles, geographical miles, sea miles, and nautical miles, and they have differed greatly in magnitude, some of the values providing 10, 12, 15, and 60 miles to a degree. The British and the U.S. nautical miles were each derived by taking 60 nautical miles per degree, but the values adopted were not the same. The nautical mile adopted by the British Admiralty equals 6,080 British feet, while the U.S. nautical mile has had the adopted value of 1,853.248 meters, from which the equivalent 6,080.20 U.S. feet has been derived. The British foot is shorter than the U.S. foot by 1 part in 400,000, an amount which is of no importance in the ordinary transactions of everyday life but which is very important in precise measurements.

In 1929 the International Hydrographic Bureau obtained an agreement from a large number of countries to adopt a value of 1,852 meters for the nautical mile, the unit thus defined to be called the International Nautical Mile. However, at the same time Great Britain, the U.S.S.R., and the United States did not accept this value, each country preferring to retain the nautical mile to which it had been accustomed.

Finally, in 1953 an informal group from the Department of Defense and the Department of Commerce considered a proposal for international standardization of abbreviations for the knot and the mile. At this meeting the general situation regarding the nautical mile was discussed, and the belief was expressed that a change from 1,853.248 meters to 1,852 meters would not affect nautical charts, the calibration of navigational instruments, or navigation. Because there seemed to be no sound reason why the International Nautical Mile should not be adopted in this country, the Departments of Commerce and Defense agreed to accept this value as of July 1, 1954, the announcement to be made by the National Bureau of Standards.

Identical directives, in the names of the two departments, have been mutually adopted. The Department of Commerce directive is as follows:

Adoption of International Nautical Mile

I. Purpose

To adopt the International Nautical Mile for use as a standard value within the Department of Commerce.

II. Implementation

After the effective date of this directive, the International Nautical Mile (1,852 meters, 6,076.10333 . . . feet), shall be used within the Department of Commerce as the standard length of the nautical mile.

III. Effective date

This directive is effective 1 July 1954.

It will be noted that in the forgoing announcement one of the equivalents of the international nautical mile is stated as 6,076.10333 . . . feet. The three dots following the last digit indicate a continuing repetition of the digit 3.

By reference to appendix 5, it will be found that the equivalent of the international nautical mile in feet is stated as approximately 6,076.11549 international feet; this latest value represents no change in the length of the nautical mile—1852 meters—but is merely a restatement of the equivalent in terms of the international foot which is shorter than the former United States foot by two parts in a million.

Appendix 5. The United States Yard and Pound

The following statement of the Department of Commerce concerning a refinement of values for the yard and the avoirdupois pound, approved June 25, 1959, is quoted from the Federal Register of July 1, 1959:

Refinement of Values for the Yard and the Pound

Background. The National Bureau of Standards, founded in 1901, is authorized by statute (U.S. Code, Title 15, Ch. 7, sec. 272) to undertake "The custody, maintenance, and development of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards. * * *" Under this authority the National Bureau of Standards has sought to refine and extend the standards to meet the continuing requirements of science and industry for increased accuracy and uniformity of measurement.

Since 1893 the National Bureau of Standards and its predecessor agency, the Office of Standard Weights and Measures of the Treasury Department, have derived the yard and the pound and the multiples and submultiples of these units from metric standards, namely the international meter and the international kilogram. The original announcement of this derivation, together with the numerical ratios upon which the derivations were based, is given in Bulletin 26, "Fundamental Standards of Length and Mass", of the U.S. Coast and Geodetic Survey, approved for publication April 5, 1893, by the Secretary of the Treasury. An amendment to the 1893 Bulletin was made in 1894 in which there was a small adjustment in the pound-kilogram ratio to bring it into closer agreement with the British Imperial pound.

In the latter half of the period since 1893 minor but troublesome discrepancies have developed among various groups, both in this country and abroad, that are concerned with very accurate measurements involving yard and pound units or their customary multiples and submultiples. As a result of study and negotiation, it has developed that most of the discrepancies can be resolved and a high degree of measurement uniformity obtained by small refinements of the ratios defined in the 1893–94 bulletins relating the yard and pound to the meter and kilogram. Accordingly, the following announcement is made:

Announcement. Effective July 1, 1959, all calibrations in the U.S. customary system of weights and measures carried out by the National Bureau of Standards will continue to be based upon metric measurement standards and except those for the U.S. Coast and Geodetic Survey as noted below, will be made in terms of the following exact equivalents and appropriate multiples and submultiples:

$$1 \text{ yard} = 0.914\,4 \text{ meter}$$

$$1 \text{ pound (avoirdupois)} = 0.453\,592\,37 \text{ kilogram}$$

Currently, the units defined by these same equivalents, which have been designated as the International Yard and the International Pound, respectively, will be used by the National Standards Laboratories of Australia, Canada, New Zealand, South Africa, and United Kingdom; thus there will be brought about international accord on the yard and pound by the English-speaking nations of the world, in precise measurements involving these basic units.

Any data expressed in feet derived from and published as a result of geodetic surveys within the United States will continue to bear the following relationship as defined in 1893:

$$1 \text{ foot} = \frac{1200}{3937} \text{ meter}$$

The foot unit defined by this equation shall be referred to as the U.S. Survey Foot and it shall continue to be used, for the purpose given herein, until such a time as it becomes desirable and expedient to readjust the basic geodetic survey networks in the United States, after which the ratio of a yard, equal to 0.914 4 meter shall apply.

Relation to Previously Defined Standards

In 1866 (U.S. Code 1952 Ed., Titles 15, Ch. 6, secs. 204 and 205) the Congress legalized the use of the metric system within the United States. The law also established approximate equivalents between customary and metric measures. The above ratios between the yard and pound and metric measures as well as those defined in the 1893–94 bulletins are consistent with the ratios established by Congress in 1866 within the limits of accuracy by which the latter are expressed.

Yard. In the 1893 Bulletin the yard was defined as:

$$1 \text{ yard} = \frac{3600}{3937} \text{ meter}$$

which results in the approximate relation:

$$1 \text{ yard} = 0.914\,401\,83 \text{ meter}$$

Thus the new value for the yard is smaller by 2 parts in one million than the 1893 yard. Numerical measures expressed in terms of the new unit will, therefore, be increased by 2 parts in one million.

Pound. The pound was defined in the 1893 Bulletin as:

$$1 \text{ pound (avoirdupois)} = \frac{1}{2.20462} \text{ kilogram}$$

The 1894 amendment based on a recent determination of the British Imperial pound, gave the ratio as:

$$1 \text{ pound (avoirdupois)} = \frac{1}{2.20462234} \text{ kilogram}$$

which results in the approximate relation:

$$1 \text{ pound (avoirdupois)} = 0.453\ 592\ 4277 \text{ kilogram}$$

Thus the new value for the pound is smaller by about 1 part in 10 million than the 1894 pound. Numerical measures expressed in terms of the new unit will, therefore, be increased by about 1 part in 10 million.

Changes concern science and precision tools. Such small changes are beyond the limits of accuracy by which many reference standards are now calibrated by the National Bureau of Standards, including the standards furnished to or calibrated for the State governments. Therefore, the refinements in the definitions of the yard and the pound will have no effect at all upon ordinary trade and commerce. The differences are significant, however, in a number of very precise metrological determinations such as are found in the precision machine tool and instrument industries and in certain scientific activities.

Standard inch. The value for the inch, derived from the value for the yard effective July 1, 1959, is exactly equivalent to 25.4 millimeters. It may be noted that this value was approved by the American Standards Association for "Inch-millimeter Conversion for Industrial Use" in 1933 (ASA Standard B48.1–1933), was adopted by the National Advisory Committee for Aeronautics in 1952, and has been adopted by many standardizing organizations in other countries.

Relation to grain. The new conversion factor for the pound is exactly divisable by 7 and results in the following exact value for the grain:

$$1 \text{ grain} = 0.064\ 798\ 91 \text{ gram}$$

The grain is the common unit of the avoirdupois, apothecary, and troy systems, there being 7000 grains in the avoirdupois pound and 5760 grains in the apothecary pound and in the troy pound.

Nautical mile. On July 1, 1954, it was announced that the Secretary of Commerce and the Secretary of Defense had agreed officially that the International Nautical Mile would henceforth be used within their respective departments. The International Nautical Mile is based on the meter and is equal to 1852 meters. Based on the yard-meter relationship then in use, the International Nautical Mile was shown as being equivalent to 6,076.10333 feet. Under the new conversion factor, the International Nautical Mile is equivalent to 6,076.11549 International feet approximately.

(For a detailed treatment of the Federal basis for weights and measures, see National Bureau of Standards Circular 593, The Federal Basis for Weights and Measures, for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., price 30 cents.)

[SEAL]

A. V. ASTIN,
Director,
National Bureau of Standards.

H. ARNOLD KARO,
Rear Admiral,
Director, Coast and Geodetic Survey.

Approved: June 25, 1959.
F. H. MUELLER,
Under Secretary of Commerce.

[F.R. Doc. 59-5442; Filed, June 30, 1959; 8:45 a.m.]

Appendix 6. Adoption of the Wavelength Definition of the Meter

The following account concerning the adoption of the wavelength definition of the meter is quoted from the National Bureau of Standards Technical News Bulletin of December 1960:

Wavelength of Kr^{86} Light Becomes New International Standard of Length

On October 14, 1960 the world adopted a new international standard of length—a wavelength of light—replacing the meter bar which had served as the standard for over 70 years. The action was taken by the 11th General Conference on Weights and Measures, which met in Paris.

Dr. Allen V. Astin, NBS Director, headed the American delegation to the Conference. The delegation also included Louis Polk, President, Sheffield Corporation; Elmer Hutchisson, Director, American Institute of Physics; A. G. McNish, Chief, Metrology Division, NBS; T. H. Osgood, U.S. Scientific Attaché, London, and Marten Van Heuven and Benjamin Bock, U.S. State Department.

Other actions taken by the Conference included the establishment of a central facility at the International Bureau of Weights and Measures for international coordination of radiation measurements, confirmation of a new definition of the second of time, and adoption of refinements in the scales for temperature measurements.

The new definition of the meter as 1,650,763.73 wavelengths of the orange-red line of krypton 86 will replace the platinum-iridium meter bar which has been kept at Paris as an international standard for length since 1889 under the Treaty of the Meter.

These actions of the General Conference are of great importance to those engaged in precision measurements in science and industry. For many years the world has relied on a material standard of length—the distance between two engraved lines on the International Meter Bar kept at Paris. Duplicates of the International Standard were maintained in the standards laboratories of other countries of the world. From time to time it was necessary to return these duplicates to Paris for recalibration, and occasionally discrepant results were obtained in these recalibrations. Also, there was doubt in the minds of some scientists regarding the stability of the International Meter Bar. The new definition of the meter relates it to a constant of nature, the wavelength of a specified kind of light, which is believed to be immutable and can be reproduced with great accuracy in any well-equipped laboratory. Thus it is no longer necessary to return the national standards of length to Paris at periodic intervals in order to keep length measurements on a uniform basis throughout the world. Also it is possible to measure some dimensions more accurately in terms of the new definition than was possible before. The meter bars which have served as standards of length throughout the world for over 70 years will not be discarded or placed in museums because of this decision, the Conference said. They will remain important because of the ease with which they can be used for certain types of measurement and for comparison measurements between national laboratories.

This new definition of the meter will not materially change the measurement of length nor in any way the relation between the English and Metric units. Careful experiments performed at the National Bureau of Standards by the team of A. G. Strang, K. F. Nefflen, J. B. Saunders, B. L. Page, and D. B. Spangenberg immediately prior to the meeting of the Conference confirmed that the wavelength standard and the metal standard are in satisfactory agreement. The inch now becomes equal to 41,929.399 wavelengths of the krypton light.

Similar measurements performed by the National Research Council in Canada, by Dr. K. M. Baird and his associates, are in substantial agreement with the National Bureau of Standards results. By adoption of the new definition, the standard of length which has been used by spectroscopists for the past 50 years is brought into agreement with that used in other branches of science, thus increasing the unification of systems of measurement throughout the scientific world.

The orange-red wavelength is precisely described as the wavelength in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the atom of krypton 86.

The author acknowledges with gratitude the assistance he has received in the earlier stages of the preparation of this publication from Ralph W. Smith, himself an ardent worker for uniform weights and measures in the United States, and in all stages from Malcolm W. Jensen.

Appendix 7

National Bureau of Standards

METRIC SYSTEM OF WEIGHTS AND MEASURES

Guidelines for Use

Section 403 of Pub. L. 93-380 states the policy of the United States to encourage educational agencies and institutions to prepare students to use the metric system of measurement as part of the regular education program and authorizes the U.S. Commissioner of Education to carry out a program of grants and contracts to fulfill this policy. Subsection 403 (a)(3) states, "For the purposes of this section, the term 'metric system of measurement' means the International System of Units as established by the General Conference of Weights and Measures in 1960 and interpreted or modified for the United States by the Secretary of Commerce." The National Bureau of Standards is responsible for "the custody, maintenance, and development of the national standards of measurement" (15 U.S.C. 272), and the Secretary has designated NBS to implement his responsibilities under subsection 403(a)(3). Pursuant to his authority under section 403, the U.S. Commissioner of Education has requested that NBS publish guidelines for use of the International System of Units, as interpreted and modified for the United States. Accordingly, and in implementation of the Secretary's responsibilities under subsection 403(a)(3), the following tables and associated materials set forth guidelines for use of the International System of Units (hereinafter "SI"), as interpreted and modified for the United States by NBS on behalf of the Secretary of Commerce.

The SI is constructed from seven base units for independent quantities plus two supplementary units for plane angle and solid angle, listed in Table 1.

TABLE 1

Quantity	Name	Symbol
	SI BASE UNITS	
length	metre (meter)[1]	m
mass[2]	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature.[3]	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd
	SI SUPPLEMENTARY UNITS	
plane angle	radian	rad
solid angle	steradian	sr

[1] Both spellings are acceptable.

[2] "Weight" is the commonly used term for "mass."

[3] It is acceptable to use the Celsius temperature (symbol t) defined by $t=T-T_0$ where T is the thermodynamic temperature, expressed in kelvins, and $T_0=273.15$ K by definition. The unit "degree Celsius" is thus equal to the unit "kelvin" when used as an interval or difference of temperature. Celsius temperature is expressed in degrees Celsius (symbol °C).

Units for all other quantities are derived from these nine units. In Table 2 are listed 17 SI derived units with special names which were derived from the base and supplementary units in a coherent manner, which means in brief, that they are expressed as products and ratios of the nine base and supplementary units without numerical factors.

TABLE 2.—*SI derived units with special names*

Quantity	SI unit		
	Name	Symbol	Expression in terms of other units
frequency	hertz	Hz	s^{-1}
force	newton	N	$m\cdot kg/s^2$
pressure, stress	pascal	Pa	N/m^2
energy, work, quantity of heat.	joule	J	$N\cdot m$
power, radiant flux	watt	W	J/s
quantity of electricity, electric charge.	coulomb	C	$A\cdot s$
electric potential, potential difference, electromotive force.	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
conductance	siemens	S	A/V
magnetic flux	weber	Wb	$V\cdot s$
magnetic flux density.	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	$cd\cdot sr$
illuminance	lux	lx	lm/m^2
activity (radioactive).	becquerel	Bq	s^{-1}
absorbed dose	gray	Gy	J/kg

All other SI derived units, such as those in tables 3 and 4, are similarly derived in a coherent manner from the 26 base, supplementary, and special-name SI units.

TABLE 3.—*Examples of SI derived units, expressed in terms of base units*

Quantity	SI unit	Unit symbol
area	square metre	m^2
volume	cubic metre	m^3
speed, velocity	metre per second	m/s
acceleration	metre per second squared.	m/s^2
wave number	1 per metre	m^{-1}
density, mass density.	kilogram per cubic metre.	kg/m^3
current density	ampere per square metre.	A/m^2
magnetic field strength.	ampere per metre	A/m
concentration (of amount of substance).	mole per cubic metre	mol/m^3
specific volume	cubic metre per kilogram.	m^3/kg
luminance	candela per square metre.	cd/m^2

TABLE 4.—*Examples of SI derived units expressed by means of special names*

Quantity	Name	Unit symbol
dynamic viscosity	pascal second	$Pa\cdot s$
moment of force	metre newton	$N\cdot m$
surface tension	newton per metre	N/m
heat flux density, irradiance.	watt per square metre.	W/m^2
heat capacity, entropy.	joule per kelvin	J/K
specific heat capacity, specific entropy.	joule per kilogram kelvin.	$J/(kg\cdot K)$
specific energy	joule per kilogram	J/kg
thermal conductivity.	watt per metre kelvin.	$W/(m\cdot K)$
energy density	joule per cubic metre.	J/m^3
electric field strength.	volt per metre	V/m
electric charge density.	coulomb per cubic metre.	C/m^3
electric flux density.	coulomb per square metre.	C/m^2
permittivity	farad per metre	F/m
permeability	henry per metre	H/m
molar energy	joule per mole	J/mol
molar entropy, molar heat capacity.	joule per mole kelvin	$J/(mol\cdot K)$

For use with the SI units there is a set of 16 prefixes (see table 5) to form multiples and submultiples of these units.

TABLE 5.—*SI prefixes*

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Certain units which are not part of the SI are used so widely that it is impractical to abandon them. The units that are accepted for continued use in the United States with the International System are listed in table 6.

TABLE 6.—*Units in use with the international system*

Name	Symbol	Value in SI unit
minute	min	1 min=60 s
hour	h	1 h=60 min=3 600 s
day	d	1 d=24 h=86 400 s
degree	°	1°=(π/180) rad
minute	′	1′=(1/60)°=(π/10 800) rad
second	″	1″=(1/60)′=(π/648 000) rad
litre (liter)[1]	l	1 l=1 $dm^3=10^{-3}m^3$
metric ton or tonne	t	1 t=10^3 kg

[1] Both spellings are acceptable.

In those cases where their usage is already well established, the use, for a limited time, of the following units is accepted, subject to future review.

nautical mile	hectare	gal[1]
knot	barn	curie
angstrom	bar	rontgen
standard atmosphere	are	rad

[1] Not gallon.

Metric units and their symbols other than those enumerated above are not part of the International System of Units. Accordingly, the following units and terms listed in the table of metric units in section 2 of the act of July 28, 1866, that legalized the metric system of weights and measures in the United States, are no longer accepted for use in the United States:

myriameter
stere
millier or tonneau
quintal
myriagram
kilo (for kilogram)

For more information regarding the International System of Units, contact the Metric Information Office, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C. 20234.

Dated: June 1, 1975.

RICHARD W. ROBERTS,
Director.

[FR Doc.75-15798 Filed 6-18-75;8:45 am]

Note: The kilogram is the only SI unit with a prefix. Because double prefixes are not to be used, the prefixes of Table 5, in the case of mass, are to be used with gram and not with kilogram.

Appendix 8

DEPARTMENT OF COMMERCE

National Bureau of Standards

CUSTOMARY SYSTEM OF WEIGHTS AND MEASURES

Commercial Weights and Measures Units

By virtue of the authority vested in the Secretary of Commerce by 15 U.S.C. 272 and delegated to the National Bureau of Standards by Department Order 90–A, the Bureau is charged with the responsibility for "The custody, maintenance, and development of the national standards of measurement, * * *." The method employed for disseminating information on weights and measures units has been through official National Bureau of Standards publications. However, all such units have never been listed together in any Federal legislation or in the FEDERAL REGISTER. On February 27, 1968, in the House Committee on Science and Astronautics Report No. 1107, accompanying H.R. 13058, legislation to repeal the Standard Container Act of August 31, 1916 (39 Stat. 673; 15 U.S.C. 251–256), and the Standard Container Act of May 21, 1928 (45 Stat. 685; 15 U.S.C. 257–257i), and amend the Fair Packaging and Labeling Act of November 3, 1966 (80 Stat. 1296; 15 U.S.C. 1451), the following Committee view was expressed:

Testimony revealed that although standard weights and measures are defined in publications by the Bureau of Standards, these definitions are not defined by law nor have they been published in the FEDERAL REGISTER. Consequently, the Committee recommends that the Secretary of Commerce cause to be published in the FEDERAL REGISTER a listing of the common weights and measures used in normal commerce throughout the United States and relate them to the standards developed in accordance with existing law, 15 U.S.C. 272.

Commercial units of weight and measure in common use are based on the yard and the avoirdupois pound. The yard and avoirdupois pound were last defined in the FEDERAL REGISTER of July 1, 1959, in terms of the national standards of length and mass: The meter and the National Prototype Kilogram. From the two units, the yard and the pound, are derived all other U.S. Customary multiple and submultiple units that will be found in ordinary commerce. They are defined as:

1 yard=0.914 4 meter [1]
1 pound (avoirdupois)=0.453 592 37 kilogram [1]

LINEAR MEASURE
U.S. CUSTOMARY

12 inches=1 foot=0.304 8 meter [1]
3 feet=1 yard=0.914 4 meter [1]
5,280 feet=1 statute mile=1.609 kilometers
6,076.115 feet=1 International Nautical Mile=1.852 kilometers [1]

METRIC

10 millimeters=1 centimeter
10 centimeters=1 decimeter
10 decimeters=1 meter
10 meters=1 dekameter
10 dekameters=1 hectometer
10 hectometers=1 kilometer

AREA MEASURE
U.S. CUSTOMARY

144 square inches=1 square foot=0.092 9 square meter
9 square feet=1 square yard=0.836 1 square meter
43,560 square feet=1 acre=0.404 7 hectare
640 acres=1 square mile=259 hectares
1 square mile=1 section=259 hectares
36 sections=1 township=932 4 hectares

METRIC

100 square millimeters=1 square centimeter
10,000 square centimeters=1 square meter
100 square meters=1 are
100 ares=1 hectare
100 hectares=1 square kilometer

WEIGHT
U.S. CUSTOMARY (AVOIRDUPOIS)

437.5 grains=1 ounce=28.349 5 grams
7,000 grains=1 pound=0.453 592 37 kilogram
16 ounces=1 pound=0.453 592 37 kilogram
2,000 pounds=1 short ton=0.907 2 metric ton
2,240 pounds=1 long ton=1.016 metric tons

METRIC

10 milligrams=1 centigram
10 centigrams=1 decigram
10 decigrams=1 gram
10 grams=1 dekagram
10 dekagrams=1 hectogram
10 hectograms=1 kilogram
1,000 kilograms=1 metric ton

[1] Denotes exact figures.

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Appendix 8—Continued

CAPACITY, OR VOLUME, LIQUID MEASURE

U.S. CUSTOMARY

1 gallon=231 cubic inches=3.785 4 liters
4 fluid ounces=1 gill=0.118 3 liter
4 gills=1 pint=0.473 2 liter
2 pints=1 quart=0.946 4 liter
4 quarts=1 gallon=3.785 4 liters

METRIC

10 milliliters=1 centiliter
10 centiliters=1 deciliter
10 deciliters=1 liter
10 liters=1 dekaliter
10 dekaliters=1 hectoliter
10 hectoliters=1 kiloliter

CAPACITY, OR VOLUME, DRY MEASURE

U.S. CUSTOMARY

1 bushel=2,150.42 cubic inches=35.239 1 liters
2 dry pints=1 dry quart=1.101 2 liters
8 dry quarts=1 peck=8.809 8 liters
4 pecks=1 bushel=35.239 1 liters

The accepted volume of a barrel in the United States varies significantly depending both on the commodity for which it is used and on how it is defined in State law (varying from State-to-State).

METRIC

The volumetric units are the same for both liquid and dry measure in the Metric System.

CUBIC MEASURE

U.S. CUSTOMARY

1,728 cubic inches=1 cubic foot=0.028 316 8 cubic meter
27 cubic feet=1 cubic yard=0.764 554 9 cubic meter

METRIC

1,000 cubic millimeters=1 cubic centimeter
1,000 cubic centimeters=1 cubic decimeter
1,000 cubic decimeters=1 cubic meter

SPECIAL UNITS

The unit used for the sale of firewood is the cord of 128 cubic feet.

The unit used for the sale of precious stones is the Metric Carat of 200 milligrams.

The units used for over-the-counter sales of precious metals in the United States are troy units.

TROY WEIGHT

24 grains=1 pennyweight=1.555 17 grams
20 pennyweights=1 ounce troy=31.103 47 grams
12 ounces troy=1 pound troy=0.373 242 kilogram

The apothecaries system of units, once widely used in the United States for pharmaceutical purposes, is now used only very little. Usage of the Metric System has replaced the apothecaries system at the manufacturing level, and at most of the retail level.

ELECTRICITY AND NATURAL GAS

When a consumer is billed for having used electricty, what has been sold is electrical energy, and that energy is expressed in terms of kilowatt-hours. One kilowatt-hour equals 3,600,000 joules (the joule is the unit of energy in the International System of Units).

Consumption of natural gas normally is expressed in terms of therms. One therm equals 105,480,400 joules.

Dated: July 15, 1968.

A. V. ASTIN, *Director.*

[F.R. Doc. 68-8953; Filed, July 26, 1968; 8:45 a.m.]

Appendix 9

DEPARTMENT OF COMMERCE

National Bureau of Standards

CUSTOMARY SYSTEM OF WEIGHTS AND MEASURES

Commercial Weights and Measures Units

In the Federal Register of July 27, 1968 (33 FR 10755), the National Bureau of Standards, in accordance with a recommendation of the House Committee on Science and Astronautics and pursuant to the responsibility of the National Bureau of Standards for "the custody, maintenance, and development of the national standards of measurement" (15 U.S.C. 272), published a listing of the common weights and measures used in normal commerce throughout the United States, and related them to the standards developed in accordance with existing law. In connection with the notice of July 27, 1968, the following explanatory material will assist in the proper interpretation and application of the data in column three under "Linear Measurement, U.S. Customary," and under "Area Measurement, U.S. Customary":

As the July 27, 1968 notice states, all U.S. Customary Units of linear and area measurement that will be found in ordinary commerce are derived from the yard. The yard was last defined in a notice in the Federal Register of July 1, 1959 (24 FR 5348), as being exactly equal to 0.9144 meter.

The foot defined by the equations:

3 feet = 1 yard = 0.9144 meter, exactly
1 foot = 0.3048 meter, exactly

is known as the International Foot. In addition, the July 1, 1959 notice defines the U.S. Survey Foot as follows:

$$1 \text{ survey foot} = \frac{1200}{3937} \text{ meter, exactly}$$

or

1 survey foot = 0.304 800 61 meter, approximately

Accordingly, it is necessary to differentiate between the international foot, used for engineering, and the U.S. survey foot, used for mapping and land measurement. The metric equivalents listed in the July 27, 1968 notice for land measurements: statute mile (U.S. survey mile), acre, square mile, section, and township are approximate; metric equivalents to more figures can be determined from the survey foot. For example, the U.S. survey mile equals 1.609 347 kilometers, approximately, whereas the international mile equals 1.609 344 kilometers, exactly. Metric equivalents of all surveyor's units, e.g., links, rods, and chains, are derived from the survey foot.

The relationship

1 international nautical mile = 1.852 kilometers

is exact, but the relationship

6 076.115 international feet = 1 international nautical mile

is not exact.

Dated: January 17, 1975.

Richard W. Roberts,
Director.

Note.—This document is republished from the issue of January 22, 1975 (40 FR 3486).

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