A Brief History of Measurement Systems

"Weights and measures may be ranked among the necessaries of life to every individual of human society. They enter into the economical arrangements and daily concerns of every family. They are necessary to every occupation of human industry; to the distribution and security of every species of property; to every transaction of trade and commerce; to the labors of the husbandman; to the ingenuity of the artificer; to the studies of the philosopher; to the researches of the antiquarian; to the navigation of the mariner, and the marches of the soldier; to all the exchanges of peace, and all the operations of war. The knowledge of them, as in established use, is among the first elements of education, and is often learned by those who learn nothing else, not even to read and write. This knowledge is riveted in the memory by the habitual application of it to the employments of men throughout life."

JOHN QUINCY ADAMS - Report to the Congress, 1821

Weights and measures were among the earliest tools invented by man. Primitive societies needed rudimentary measures for many tasks: constructing dwellings of an appropriate size and shape, fashioning clothing and bartering food or raw materials.

Man understandably turned first to parts of his body and his natural surroundings for measuring instruments. Early Babylonian and Egyptian records, and the Bible, indicate that length was first measured with the forearm, hand, or finger and that time was measured by the periods of the sun, moon, and other heavenly bodies. When it was necessary to compare the capacities of containers such as gourds or clay or metal vessels, they were filled with plant seeds that were then counted to measure the volumes. With the development of scales as a means for weighing, seeds and stones served as standards. For instance, the "carat," still used as a mass unit for gems, is derived from the carob seed.

As societies evolved, measurements became more complex. The invention of numbering systems and the science of mathematics made it possible to create whole systems of measurement units suited to trade and commerce, land division, taxation, and scientific research. For these more sophisticated uses, it was necessary not only to weigh and measure more complex things it was also necessary to do it accurately time after time and in different places. However, with limited international exchange of goods and communication of ideas, it is not surprising that different systems for the same purpose developed and became established in different parts of the world - even in different parts of the same country.

THE ENGLISH SYSTEM

The measurement system commonly used in the United States today is nearly the same as that brought by the colonists from England. These measures had their origins in a variety of cultures –Babylonian, Egyptian, Roman, Anglo-Saxon, and Norman French. The ancient "digit," "palm," "span" and "cubic" units of length slowly lost preference to the length units "inch," "foot," and "yard."

Roman contributions include the use of 12 as a base number (the foot is divided into 12 inches) and the words from which we derive many of our present measurement unit names. For example, the 12 divisions of the Roman "pes," or foot were called unciae. Our words "inch" and "ounce" are both derived from that Latin word.

The "yard" as a measure of length can be traced back to early Saxon kings. They wore a sash or girdle around the waist that could be removed and used as a convenient measuring device. The word "yard" comes from the Saxon word "gird" meaning the circumference of a person's waist.

Standardizing various units and combining them into loosely related systems of measurement units sometimes occurred in fascinating ways. Tradition holds that King Henry I decreed that a yard should be the distance from the tip of his nose to the end of his outstretched thumb. The length of a furlong (or furrow-long) was established by early Tudor rulers as 220 yards. This led Queen Elizabeth I to declare in the 16th century, that henceforth the traditional Roman mile of 5000 feet would be replaced by one of 5280 feet, making the mile exactly eight furlongs and providing a convenient relationship between the furlong and the mile.

Thus, through royal edicts, England by the 18th century had achieved a greater degree of standardization than other European countries. The English units were well suited to commerce and trade because they had been developed and refined to meet commercial needs. Through English colonization and its dominance of world commerce during the 17th, 18th, and l9th centuries, the English system of measurement units became established in many parts of the world, including the American colonies.

However, standards still differed to an extent undesirable for commerce, even among the 13 American colonies. The need for greater uniformity led to clauses in the Articles of Confederation (ratified by the original colonies in 1781) and the Constitution of the United States (ratified in 1790) that gave Congress the power to fix uniform standards for weights and measures. Today, standards supplied to all the states by the National Institute of Standards and Technology assure uniformity throughout the country.

THE METRIC SYSTEM

The need for a single worldwide coordinated measurement system was recognized over 300 years ago. Gabriel Mouton, Vicar of St. Paul's Church in Lyons and an astronomer, proposed in 1670 a comprehensive decimal measurement system based on the length of one minute of arc of a great circle of the Earth. Mouton also proposed the swing length of a pendulum with a frequency of one beat per second as the unit of length. A pendulum with this beat would have been fairly easily reproducible, thus facilitating the widespread distribution of uniform standards. Other proposals were made, but more than a century elapsed before any action was taken. **(*Please see footnote regarding this reference to Gabriel Mouton's proposed swing length of a pendulum with frequency of one beat per second.*)**

In 1790, in the midst of the French Revolution, the National Assembly of France requested the French Academy of Sciences to "deduce an invariable standard for all the measures and all the weights."

The Commission appointed by the Academy created a system that was, at once, simple and scientific. The unit of length was to be a portion of the Earth's circumference. Measures for capacity (volume) and mass were to be derived from the unit of length, thus relating the basic units of the system to each other and to nature. Furthermore, larger and smaller multiples of each unit were to be created by multiplying or dividing the basic units by 10 and its powers. This feature provided a great convenience to users of the system, by eliminating the need for such calculations as dividing by 16 (to convert ounces to pounds) or by 12 (to convert inches to feet). Similar calculations in the metric system could be performed simply by shifting the decimal point Thus, the metric system is a "base-10" or "decimal" system.

The Commission assigned the name metre - meter - to the unit of length. This name was derived from the Greek word metron, meaning "a measure." The physical standard representing the meter was to be constructed so that it would equal one ten-millionth of the distance from the North Pole to the equator along the meridian running near Dunkirk in France and Barcelona in Spain.

The initial metric unit of mass, the "gram," was defined as the mass of one cubic centimeter (a cube that is 0.01 meter on each side) of water at its temperature of maximum density. The cubic decimeter (a cube 0. 1 meter on each side) was chosen as the unit for capacity. The fluid volume measurement for the cubic decimeter was given the name "liter."

Although the metric system was not accepted with enthusiasm at first, adoption by other nations occurred steadily after France made its use compulsory in 1840. The standardized structure and decimal features of the metric system made it well suited for scientific and engineering work. Consequently, it is not surprising that the rapid spread of the system coincided with an age of rapid technological development. In the United States, by Act of Congress in 1866, it became “lawful throughout the United States of America to employ the weights and measures of the metric system in all contracts, dealings or court proceedings.”

By the late 1860s, even better metric standards were needed to keep pace with scientific advances. In 1875, an international agreement, known as the Meter Convention, set up well-defined metric standards for length and mass and established permanent mechanisms to recommend and adopt further refinements in the metric system. This agreement, commonly called the "Treaty of the Meter” in the United States, was signed by 17 countries, including the United States. As a result of the Treaty, metric standards were constructed and distributed to each nation that ratified the Convention. Since 1893, the internationally adopted-to metric standards have served as the fundamental measurement standards of the United States.

By 1900 a total of 35 nations -- including the major nations of continental Europe and most of South America -- had officially accepted the metric system.

In 1960, the General Conference on Weights and Measures, the diplomatic organization made up of the signatory nations to the Meter Convention, adopted an extensive revision and simplification of the system. Seven units -- the meter (for length), the kilogram (for mass), the second (for time), the ampere (for electric current), the kelvin (for thermodynamic temperature), the mole (for amount of substance), and the candela (for luminous intensity) -- were established as the base units for the system. The name Systeme International d'Unites (International System of Units), with the international abbreviation SI, was adopted for this modern metric system.

In 1971, the U.S. Secretary of Commerce, in transmitting to Congress the results of a 3-year study authorized by the Metric Study Act of 1968, recommended that the U.S. change to predominant use of the metric system through a coordinated 10-year national program. The Congress responded by enacting the Metric Conversion Act of 1975, calling for voluntary conversion. Amendments to the Act in 1988 designated the metric system as the "preferred system of weights and measures for United States trade and commerce."

Measurement science continues to develop more precise and easily reproducible ways of defining measurement units. The working organizations of the General Conference on Weights and Measures coordinate the exchange of information about the use and refinement of the metric system and make recommendations concerning improvements in the system and its related standards. The General Conference meets periodically to ratify improvements. Additions and improvements to SI were made by the General Conference in 1964, 1967-1968, 1971, 1975, 1979, 1983, 1991, and 1995.

Based on NBS Special Publication; 304A, Reissued September 1974 by NIST. Copy is available from the Government Printing Office as Stock Number 003-003-03501-7 with a Chart of the Modern Metric System.

Source: **NIST**
U.S. DEPARTMENT OF COMMERCE
Technical Administration
National Institute Of Standards And Technology

FOOTNOTE: With regard to the statement of "one beat per second", the unit Mouton proposed was decimal subdivisions of the minute of arc as known in his time, so his virgula (1/10000 of a minute) was approximately 20.5 cm. Today it would presumably have been 18.52 cm. The pendulum Mouton suggested as the practical manifestation was located in Lyon, and oscillated 3959.2 times in an hour. i.e., it was not a seconds pendulum. Leibniz independently made a similar proposal in 1673, the concept was quickly developed further, and that is when the concept of a seconds pendulum was aired. The reference, "Le Systeme Metrique Des Poids Et Mesures" by G. Bigourdan, 1901, is available from: http://smdsi.quartier-rural.org/histoire/precurs.htm. Acknowledgement is due to Egil Kvaleberg of Norway for bringing this to our attention".