

Which inch?

From time to time I read the line that goes something like:

The metre has never changed in length, only the definition has been rewritten to provide better accuracy and precision.

This poses the question of how reliable measurements were before the invention of the metric system in 1668. See <http://www.metricationmatters.com/who-invented-the-metric-system.html>

However, when you use the word 'inch' or its multiples, 'foot', 'yard', or 'mile', you are probably referring to a particular inch. To clarify this here is a chronology of the 'inch'.

Chronology of the inch

970 (about)

It is believed that King Edgar I (reigned 959–975) kept a wooden "yardstick" at Winchester as the official standard of measurement. An inch was 1/36 of this wooden stick.

1100 (about)

A traditional tale tells the story of Henry I (reigned 1100-1135) who decreed that the yard should be "*the distance from the tip of the King's nose to the end of his outstretched thumb*". Presumably, King Edgar's wooden stick had got lost in the meantime. This was probably just regulation intended to standardise measurements as there were several yards used in Britain at that time; presumably, the inch was defined as 1/36 of each of these yard sticks.

1196

King Richard the Lionheart (reigned 1189–1199) ordered the standardisation of units of measurement. In the Assize of Measures in 1196 it was stated "*Throughout the realm there shall be the same yard of the same size and it should be of iron*".

1215

The Magna Carta was signed with provisions for honest weights and measures. This document attempted to standardise measurements throughout the kingdom, although it concentrated on measures of wine and beer!

1275 (about)

About 60 years after the signing of the Magna Carta, King Edward I (reigned 1272–1307) ordered a permanent measuring stick made of iron to serve as a standard for his entire kingdom. King Edward I realised that constancy and permanence were the key to any standard. This standard became known as the "iron ulna" of the king. Edward decreed that the foot measure should be one-third the length of the "iron ulna", and the inch one thirty-sixth of the "iron ulna".

1300

King Edward I (reigned 1272-1307) defined the yard (or *Ulna*) and its divisions and multiples as follows: "*It is remembered that the Iron Ulna of our Lord the King contains three feet and no more; and the foot must contain twelve inches, measured by the correct measure of this kind of ulna; that is to say, one thirty-sixth part [of] the said ulna makes one inch, neither more nor less... It is ordained that three grains of barley, dry and round make an inch, twelve inches make a foot; three feet make an ulna; five and a half ulna makes a perch (rod); and forty perches in length and four perches in breadth make an acre.*" This law provided for two different definitions of the 'inch' – one derived from the 'Iron Ulna' and another derived from barleycorns. When an engineer, John M. Steele, first read this, he remarked: "*In the 1300's, it looks like ulnas for the royals, barleycorns for the peasants.*"

1324

King Edward II (reigned 1307-1327), confirmed the reversion back to the seed concept when he passed a law that said, "*three barleycorns, round and dry*" make an inch.

1497

A fire burned down the king's residence at Sheen. The standard of length (the Iron Ulna) must have been lost because King Henry VII (1485-1509) went back 350 years to obtain a new standard. Some think that he found the wooden yard of Edgar I and made a direct copy of the old standard.

1588

Queen Elizabeth I issued a new standard yard. The new yard was intended to introduce standards of measures more widely into British society and to remove inaccuracies associated with measurement. As a side issue, the gallon still used in the USA was part of Queen Elizabeth's measurement reforms. It is interesting to note that the definition of the various gallons at that time all depended on the length of the inch. One of these was defined as a cylindrical container 7 inches in diameter and 6 inches high (that gave a volume of 230.9 cubic inches). Other gallons of the period were 224 cubic inches and 233 cubic inches. Then, as now in the USA, gallons were commonly used for beer, wines, and spirits, so the size of the gallon was taken very seriously.

1690

The philosopher John Locke proposed a decimal measurement method based on a very small measure called a gry. The gry was to be the smallest unit in Locke's proposed decimal system of linear measurement. A gry was defined as a tenth of a line, a hundredth of an inch, and a thousandth of a (new 'philosophical') foot. From this very small standard gry an inch was to be defined as 100 gry(s). John Locke had been playing with this method for some time before he published his gry idea because, in 1679, he wrote to Robert Boyle about an object he had measured as, "... *three inches and nine gry's long, and one inch seven lines in girt*". Although John Locke's gry was never seriously considered as the basis for a real measurement, its existence does illustrate the type of discussion about standard measurements that was taking place at that time. It is interesting that John Locke devised his decimal methods some years after Bishop John Wilkins had invented his system for a "*universal measure*" in 1668. Wilkins' system was subsequently developed into the metric system we all use today.

1706

The UK parliament decreed that a gallon would, from 1707, be 231 cubic inches; they did this without specifying the size of the inch. Later, this gallon was adopted as a standard for the USA where it became known as the "*Queen Ann Wine gallon*".

1742

The Royal Society in 1742 commissioned a new standard yard. This was done using the Queen Elizabeth I yard as a model. Again, an inch was defined as 1/36 of this new yard.

1790 May 8

The French National Assembly decides that the length of the metre will be equal to the length of a pendulum with a half-period of one second. This was done in consultation with Benjamin Franklin and Thomas Jefferson in the USA.

1791 March 30

Recognising that a universal standard of measurement was needed, the French National Assembly accepted the proposal by the French Academy of Sciences that the new definition for the metre would be equal to one ten-millionth of the length of the Earth's meridian along a quadrant of the Earth, that is the distance from the equator to the north pole. To determine this length about one tenth of the Earth's circumference, from Dunquerque in France, to Barcelona in Spain, was meticulously measured. Due to lack of knowledge of the true shape of the Earth, this definition was never implemented.

1793 December 11

The French government tried to present the USA with its first metric standards as a gift. In a report, '*Le Système Métrique Décimal*', published by the Ministère du Commerce et Industrie in Paris they wrote: *Standard metres and graves (kilograms), made by the temporary Commission, were very probably distributed, at least in part, in several foreign countries. In the papers of the Committee of Public Safety, kept in the National Archives, there is a mention under the date of 21 frimaire year I (11 December 1793), that a copper metre and a copper grave both with gradations were sent to the USA through an agency for a Correspondent of the Natural History Museum, Joseph Dombey.* Note: The metre and the grave (kilogram) that Dombey carried were lost when his ship was almost lost in a storm; while pirates attacked Dombey's ship; or while Joseph was imprisoned by the English. Sadly, Joseph Dombey died in prison.

1795

A provisional metre bar was constructed of brass. The length of this bar is still the world standard for the length of a metre as all subsequent definitions have kept this same length while they changed the words

of the definitions to achieve greater accuracy and precision. The important point is that the metre has not changed since 1795. The inch, foot, yard, rod, and mile have changed several times since 1795.

1799 December 10

The French National Assembly specifies a platinum metre bar deposited in the National Archives, as the final standard of length for the whole world. A platinum rod was produced in Paris that was exactly one metre from end to end (using the 1795 metre as a model). This became the master standard for the whole world's measuring system. Known as the '*Mètre des Archives*' it became the "*universal measure*" that is the basis for the metric system we now all use.

1805

Ferdinand Hassler returned to the USA with an iron copy of the "*Mètre of the Archives*". Following the establishment of the "*Mètre of the Archives*" as the world standard for the metre, 12 iron copies of the 1799 platinum meter were made and these were said to be within 2 micrometres (2 μm) of the '*Mètre des Archives*' in Paris. One of these iron metres was given to Ferdinand Hassler to take to the USA where it became known as the "*Committee metre*". The Committee metre was soon put to good use for the Coast Survey that was carried out between 1807 and 1890.

1814

Charles Butler, a mathematics teacher at Cheam School, recorded the old legal definition of the inch to be "*three grains of sound ripe barley being taken out the middle of the ear, well dried, and laid end to end in a row*", and placed the barleycorn, not the inch, as the base unit of the English Long Measure system, from which all other units were derived. Butler was one of the first people to actually specify the exact type of barleycorn to use to measure an inch; in this he pioneered many other written standards that we now all rely on. However Butler also observed that "*... the length of the barley-corn cannot be fixed, so the inch according to this method will be uncertain*".

In 1814, there was also a standard inch measure kept in the Exchequer chamber, Guildhall in London and this was also regarded as the legal definition of the inch.

1815

The USA obtained an iron bar that was 82 inches long. This is known, from the name of its maker, as the Troughton bar. Apparently it was made sometime before 1812 and its length might have been based on the Elizabethan yard of 1588.

1824

The Queen Elizabeth I yard remained the legal British yard for over 300 years until 1824, when an Act of Parliament under George IV superseded it with a new yard. The new yard became the first "Imperial standard" and was actually the same standard that had been commissioned by the Royal Society in 1742, which in turn had been based on an earlier Queen Elizabeth I standard. The United Kingdom and most countries of the British Commonwealth on Nations then passed legislation to define the inch in terms of the Imperial Standard Yard with the British Weights and Measures Act of 1824. Interestingly, the USA was never provided with an official copy of the new UK yard!

1832

The Troughton bar obtained for the USA in 1815 was carefully measured and it was found that the length between the 27th inch and the 63rd inch was closest to the standard yard in the UK. That length, the '*Throughton yard*', (between the 27th inch and the 63rd inch of the Troughton bar) then was adopted as the legal standard of length for the USA. In the USA the inch then became 1/36 of the Throughton yard.

1834

The Imperial Standard Yard was damaged in a fire that burned down both Houses of Parliament. The 1824 standard had only lasted for 9 years and 198 days -- so much for long-term stability of the inch, the foot, the yard, and the mile!

1842

George Long in his Penny Cyclopædia, observing that standard measures had surpassed the barleycorn definition of the inch. Long noted that when a standard measure was lost or destroyed then to recover the inch measure from its original definition would involve the measurement of large numbers of barleycorns and taking their average lengths. George Long kept alive the idea that some sort of standard was needed to form the basis for all measurements.

1843

John Bouvier recorded in his law dictionary that the barleycorn was the fundamental legal measure (and therefore the basis for the inch). As many lawyers of that time would refer to the law dictionary rather than to other metrology documents, it would appear that there were actually two different inches in use in the UK at that time.

1850

Although not of direct relevance to the development of a fixed and certain inch in the UK, legislators needed be conscious of the standardisation needs of international trade. For example, there were many inches, all of different lengths, throughout Europe. Here are some of them: Amsterdam inch, Austrian inch, Bavarian inch, Bremen inch, French inch, Hamburg inch, Italian inch, Moscow inch, Portuguese inch, Rhineland inch, Russian inch, Spanish inch, Swedish inch, and Turkish inch. All of these varied quite markedly in length.

1855

A new standard yard was eventually legalised for the UK. This was based on unofficial standards that had been compared to the Imperial Standard Yard before it was damaged in 1834. In the interim, from 1834 to 1855, the UK, all of the countries of the British Commonwealth of Nations, and the USA did not have a standard yard for length so there was no standard for an inch either.

1856

The USA received a bronze yard directly derived from the UK Yard of 1855. It was named "Bronze #11". This bar became the new standard yard for the USA. Bronze #11 replaced the Throughton yard as its length was only slightly shorter than Bronze #11. Now the inch was 1/36 of Bronze #11.

1866

The Congress of the USA made it legal to use the metric system in the USA. The iron "*Committee Metre*" then became the physical standard of length for the USA from the passing of the Metric Act of 1866 until 1890.

1875

The Treaty of the Metre was signed by participating nations and the International Bureau of Weights and Measures (BIPM) was established (on international territory?) near Paris.

1876

Imperial standards of length were displayed in Trafalgar Square, London. Notably, Trafalgar Square was designed and made to be 100 metres by 100 metres.

1884

The UK signed the Metre Convention but did not comply with the clause that required signatory countries to implement the introduction of metric system units.

1885

A new Imperial Standard Yard was made of base metal. This proved to be so unstable that it shrank at the rate of one part per million in about 20 years.

1889 September 28

The first General Conference on Weights and Measures (CGPM) defined the metre as the distance between two lines on a standard bar of an alloy of platinum with ten percent iridium, measured at the melting point of ice. Great care was taken not to change the length of the metre. The platinum-iridium alloy from which these bars were made has proved to be exceptionally stable. This newly made platinum-iridium metre replaced the "Mètre des Archives" to become the "International Prototype Metre". Copies of this bar were then distributed to member nations including the UK and the USA.

1893

Experiments began to define the length of the "International Prototype Metre" in terms of the wavelength of light. Measurements were made in laboratories spread around the world; these were averaged and a possible new definition for the metre was "*the length equal to 1 650 763.73 wavelengths in a vacuum of the radiation ... of krypton-86.*" This definition was exceptionally stable, but it did not

become the official definition of the metre until 1960. Although the definition is different, the length of the metre is still the same as the 1795 metre.

1893

The yard was defined in the USA as $36/39.37$ of the "International Prototype Metre". This was the first time that the USA officially adopted the metric system as their standard for length measurements. However, this did not provide for a definition of an inch. The metric yard was divided into three parts and then these were then divided decimally into decimal parts of a metric foot. This yard is still in use in the USA where land lengths are measured in '*survey yards*' and '*survey feet*'. These yards and feet are not the same as the now more commonly used '*international foot*' of 1959.

The USA has, at different times, legally defined various yards and, by default, various inches. here is a comparison:

Name of yard	Yard length	Inch length
Troughton yard	914.421 90 mm	25.400 608 33 mm
Bronze yard #11	914.399 80 mm	25.399 994 4 mm
Mendenhall yard	914.401 83 mm	25.400 050 83 mm
1959 yard	914.4 mm	25.4 mm
<small>The Mendenhall yard, known as the "<i>survey yard</i>" and the 1959 yard, known as the "<i>International yard</i>" are still in use.</small>		

1897

It became legal to use the metric system in the UK. However the inch, the foot, and the yard were still defined in terms of the (gradually shrinking) 1885 Imperial yard.

1927 October 6

The seventh CGPM adjusted the definition of the metre to be the distance, at 0 °C, between the axes of the two central lines marked on the prototype bar of platinum-iridium, this bar being subject to one standard atmosphere of pressure and supported on two cylinders of at least one centimetre diameter, symmetrically placed in the same horizontal plane at a distance of 571 millimetres from each other.

1959

The Canadian inch of exactly 25.4 millimetres was accepted by English speaking nations as the international metric inch. The pound was also redefined as an exact number of grams. This means that all of the population of the USA now routinely use:

- ◇ metric inches (defined as 25.4 mm exactly)
- ◇ metric feet (defined as 304.8 mm exactly)
- ◇ metric yards (defined as 914.4 mm exactly)
- ◇ metric miles (defined as 1609.344 metres exactly)
- ◇ metric pounds (defined as 453.5 924 grams exactly)
- ◇ metric short tons (defined as 907.1847 kilograms exactly)
- ◇ metric long tons (defined as 1016.047 kilograms exactly)

However, most citizens of the USA do not know that they routinely use metric system measurements.

1960 October 14

The eleventh CGPM defines the metre to be equal to "*the length equal to 1 650 763.73 wavelengths in a vacuum of the radiation corresponding to the transition between the 2p₁₀ and 5d₅ quantum levels of the krypton-86 atom*". This meant that the International Prototype Metre, of 1889, was replaced by this new definition. Once again the length did not change; the new definition made it possible for many laboratories around the world to measure the length of a metre with accuracy and precision.

1983 October 21

The seventeenth CGPM defined the metre as equal to the distance travelled by light in vacuum during a time interval of $1/299,792,458$ of a second.

The krypton-86 definition of the metre was replaced and the metre was defined as "*the length of the path travelled by light in a vacuum during a time interval of 1/299 792 458 of a second*". This definition is so accurate and precise that the National Physical Laboratory (NPL) in the UK can measure the metre with an accuracy better than ± 3 parts in a hundred thousand million using an iodine-stabilised helium-neon laser.

Conclusion

Part of my motivation in researching this article was to count how many different inches there have been since the length of the metre became a definite, fixed, "*universal measure*" from 1795. For the UK, a good guess is eight different inches if we ignore the survey foot and the shrinking 1885 UK Imperial standard. And for the USA, a good guess is four, or perhaps five if you consider the use of the UK inch before 1815.

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Metric system consultant, writer, and speaker, Pat Naughtin, has helped thousands of people and hundreds of companies upgrade to the modern metric system smoothly, quickly, and so economically that they now save thousands each year when buying, processing, or selling for their businesses. Pat provides services and resources for many different trades, crafts, and professions for commercial, industrial and government metrication leaders in Asia, Europe, and in the USA. Pat's clients include the Australian Government, Google, NASA, NIST, and the metric associations of Canada, the UK, and the USA.

Pat specialises in the modern metric system based on the International System of Units (SI), but he is mostly concerned with the processes that people use for themselves, their groups, their businesses, their industries, and their nations as they go about their inevitable metrication process. See <http://www.metricationmatters.com/> for more metrication information, contact Pat at pat.naughtin@metricationmatters.com or subscribe to the free 'Metrication matters' newsletter at <http://www.metricationmatters.com/newsletter/>

