Centenary of the Convention of the Metre

INTERNATIONAL STANDARDS MANUFACTURED IN IRIDIUM-PLATINUM

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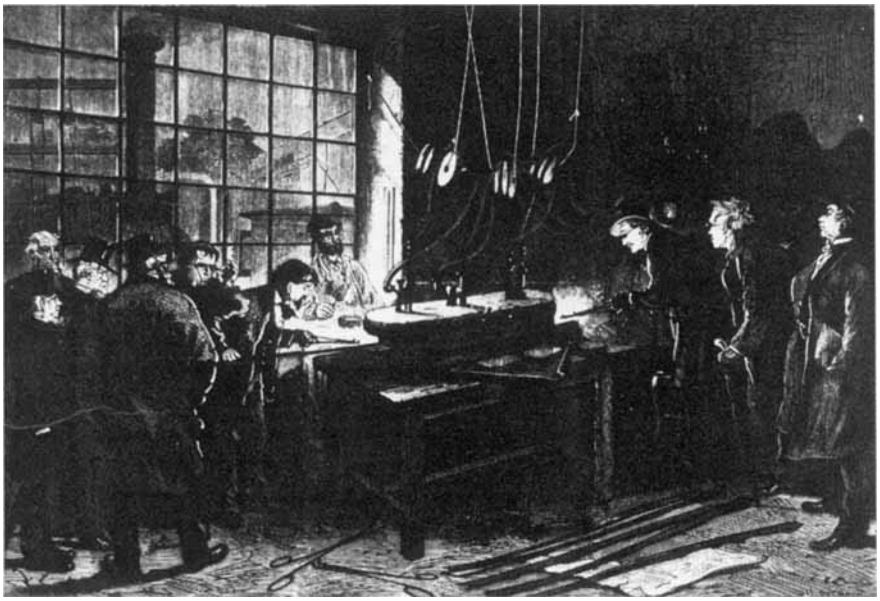
The inexorable progress of the metric system of weights and measures has resulted in a steady erosion of the traditional standards of measurement. The system, which had originated during the turmoil of the French revolution, received increasing international recognition, which became formalised one hundred years ago, and has been the basis for continuing cooperation. The first international standards, fabricated in iridium-platinum alloy, were largely produced by George Matthey.

In France, before the start of the Revolution in 1789, there had been no uniformity of weights and measures. Trading had been difficult and fraud had been easy, so in 1790 the French National Assembly called for uniform new measures to put a stop to the abuses taking place. Charles Maurice Talleyrand, Bishop of Autun, presented to the Assembly a scheme based upon "natural" measures which he proudly stated would be "for all people, for all time". This was modified by the Academy of Science, which also strongly favoured the new measures forming a decimal system as follows. The unit of length, the metre, was to be equal to the ten-millionth part of the arc of meridian between the North Pole and the equator and passing through Paris. The gram was to be the "absolute weight" of a volume of pure water, equal to the cube of the hundredth part of the metre and at the temperature of melting ice.

The length of the quarter meridian was calculated from measurements made between Dunkirk and Barcelona. The survey was by two astronomers, Jean-Baptiste Delambre and Pierre Méchain who, because of the troubled state of the country, narrowly missed losing their heads on a number of occasions after being arrested as spies. Long before this work was completed the measurement of length, area and volume based on the metre and mass (weight) based on the gram had been made obligatory by a law of 1793, with an approximate value for the metre.

After the geodetic survey and calculations for the metre and hydrostatic weighing for the gram had been completed, four bars and four cylinders of platinum were produced to form more convenient reference standards for the units than the "natural" standards. The bars, which were end standards, and the cylinders (to represent 1000 grams because this was of a more practical size) had been manufactured from native platinum by Marc Etienne Janety about 1795, possibly using the arsenic method of refining. A law of 10 December 1799 specified that one particular bar was to be the definitive standard of length throughout the Republic of France, and one cylinder the definitive standard of weight; these later became known as the Kilogramme des Archives and the Mètre des Archives. The French did not take happily to the introduction of the metric weights and measures so in 1812 Emperor Napoleon

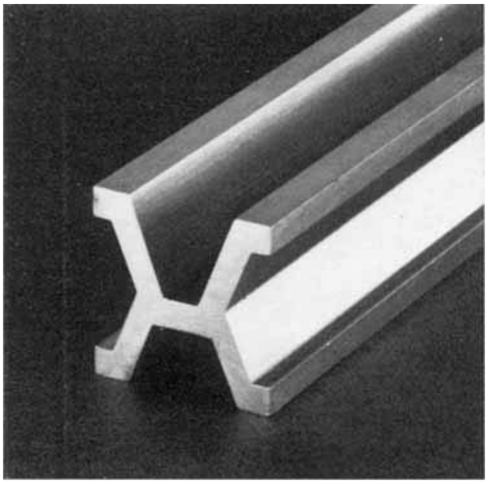


A contemporary engraving showing the melting of some of 236 kg of iridium-platinum for the standard metre at the Conservatoire des Arts et Métiers in Paris. The operation was conducted by Henri Tresca and George Matthey with Sainte-Claire Deville and Debray as technical advisers

allowed again the use of old names of measures but now with fixed new values in terms of the metre or kilogram (1000 grams). A further law of 1837 made the use of metric measures obligatory again from 1 January 1840. Elsewhere in Europe, The Netherlands had been truly metric from 1820 and Greece from 1836.

World-wide interest in the use of metric measures grew with the increase of world trade and the rapid advances of science during the first half of the nineteenth century. Prince Albert's Great Exhibition in Hyde Park in 1851 and the Paris International Exhibition in 1867 each pointed to the need for world-wide uniformity. At the Paris Exhibition a committee of delegates from many countries strongly recommended the universal adoption of metric weights and measures. This recommendation, together with similar recommendations of the Academy of Science of St. Petersburg and the International Association of Geodesy, led in 1869 to the French Government sponsoring an International Metric Commission. The objective of the Commission was to establish a purely scientific organisation for the "construction and verification with the best appliances of modern science, of new international standards of the metre and the kilogram". The Franco-Prussian war delayed the work of the Commission at the start but in 1872 the first full meeting took place with 29 states represented. Three British scientists gave valuable service throughout the life of the Commission; they were Sir George Biddel Airy, the Astronomer Royal; Henry Williams Chisholm, First Warden of the Standards, London; William Hallowes Miller, Professor of Mineralogy, Cambridge.

After two years of committee work a detailed policy had been formulated for the construction of international prototypes for the metre and kilogram, for an international



The X section originally designed by Henri Tresca for the standard metre in iridium-platinum on the grounds of its maximum rigidity. This was later abandoned on the recommendation of George Matthey who advised that it was impossible to draw the section without contamination from the dies

bureau and for establishing the means of permanent liaison between states. The French Government then convened a Diplomatic Conference of the Metre early in 1875 and on 20 May 1875 the Convention du Mètre was signed in Paris by the diplomatic representatives of 17 states. Great Britain did not join the Convention until 1884.

The International Metric Commission had decided in 1872 that the future international standards should reproduce as nearly as possible the units defined by the Archive standards, and that no attempt would be made to remeasure and recalculate the quarter meridian of the earth. It was also agreed that the material of the standards should be an alloy of 90 per cent platinum and 10 per cent iridium and that the metre should be defined by a "line" standard and not an "end" standard as the French had used. The bars were to have an X cross-section which had been designed by Henri Tresca to provide the greatest rigidity of bar for the quantity of material used. This cross-section also allowed the defining lines to be placed on the neutral plane of the bar with adequate protection against damage.

The kilograms were to be solid cylinders with height closely equal to diameter. It was also decided that in order to ensure uniformity, especially of the coefficients of expansion, between all of the standards likely to be required, all should be made from one ingot of alloy. The French Government agreed to sponsor the manufacture of the standards on behalf of the French Section of the International Metric Commission. The work was undertaken with great caution since at that time really pure platinum and iridium had never been obtained and the largest casting of platinum yet produced was one of 100 kg made by George Matthey in 1862; a 250 kg casting was now required.

Henri Sainte-Claire Deville and J. Henri Debray, who had previous experience in the refining and melting of platinum, undertook to supervise the refining of the metals and the casting of the alloy, the necessary metals of Russian origin being supplied by George Matthey. The alloying was effected in three castings of 80 kg, 85 kg and 90 kg each; the ingots were then cut into pieces of about 2 kg each. On 13 May 1874 at the Conservatoire des Arts et Métiers, the whole was remelted into a single ingot under the direction of Henri Tresca, his son Gustav Tresca, and George Matthey, with Deville and Debray in technical control. After cleaning, the ingot weighed 236 kg. Later the ingot was forged and cut into bars and these were then cold-drawn to produce the X cross-section; however, there had been some cracking, resulting in considerable scrap and only 27 metre bars weighing about 90 kg were obtained from the original ingot. (Subsequently many of these bars were found to contain cracks and fissures.) The International Committee at this stage was satisfied with the results but Deville later found that the density was barely 21.1 g/cm^3 whereas it should have been at least 21.385 g/cm^3; analysis showed that iron and ruthenium were present in appreciable quantities.

In September 1877 the International Committee of Weights and Measures established under the Convention of the Metre decided, after considerable discussion, to reject the bars made in 1874. On the advice of Matthey it was decided provisionally to abandon the X-form since he considered that the iron in the alloy might have been picked up during extensive cold drawing of the bars.

In 1878 George Matthey was invited to make two rectangular metre bars. Applying his continually advancing knowledge of the preparation and metallurgy of iridium-platinum, he made these in London from one small casting. The bars were planed, drawing being applied only to obtain the final shape, and on analysis they were found to contain only 0.23 per cent of foreign metals as compared with 2.9 per cent in those of the 1874 alloy; the density of the metal was 21.52 g/cm^3. This improvement was sufficient to encourage the Committee to have a bar of the X cross-section made in the same way. It required 448 hours of labour to plane the bar from a square to the X cross-section! The bar was delivered by Matthey in 1879; in this same year he also made three cylinders for kilogram standards.

During the years 1876 to 1878, George Matthey made other metre bars and a standard 4 metres long for the Association Géodésique Internationale. Also during this period there were differences of opinion between the members of the original French Section of the International Commission and the International Committee, which was in reality an enlargement of the original French Section. These differences of opinion were about what to do with the metal and the bars of the 1874 alloy. George Matthey was invited to produce three more bars of X cross-section by forging, rolling and then planing to final size; these also were delivered in 1879. Following extensive tests, the International Committee decided that the new International Standard was to be made from pure metals but the bars of the 1874 alloy could be used for National Standards since no significant difference between the various bars was found. In the event, practically every state requested a metre bar made from pure metals.

In August 1882 the French Government, acting again as sponsor, placed an order with Johnson Matthey for the production of 30 bars for metre standards and 40 cylinders for kilogram standards. George Matthey was left free to employ whatever methods he thought best. The density of the metal had to be 21.5 g/cm^3 at least and the composition of the alloy: platinum 90.25 to 89.75 per cent, iridium 9.75 to 10.25 per cent; other constituents were not to exceed ruthenium 0.1 per cent, iron 0.1 per cent, rhodium and/or palladium 0.15 per cent, copper, silver, gold or other metals 0.02 per cent. The cylinders were delivered by 1884 and the bars by 1887. The International Committee was responsible for the graduation of the bars and the adjustment of the cylinders. At the First General Conference of Weights and Measures in 1889, one of these metre bars was designated the International Prototype Metre and a kilogram of George Matthey's 1879 manufacture was designated the International Prototype Kilogram.

Between 1892 and 1940 nine determinations of the metre in terms of the wavelength of light were made at the International Bureau of Weights and Measures and at other national standards laboratories. These showed that the metre as defined by the International Prototype had been stable to within 3 parts in 10 millions—the mean of the nine results became the basis of the new definition of the metre in terms of the krypton-86 wavelength which was passed by the Eleventh General Conference in 1960. At the same conference the International Prototype Metre was deposed. Nevertheless, the International Prototype Kilogram remains as the ultimate standard for the world. It can thus be said that the choice of iridium-platinum for the standards was directly responsible for providing the incentive for substantial progress to be made in the refining and melting of the metals, while the standards produced in the last century have served the world impeccably.