Standard Kilogram Weights

A STORY OF PRECISION FABRICATION

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The original metric standard of weight adopted in 1799 was a kilogram fabricated from platinum. The present international standard kilogram was made nearly a century ago from 10 per cent iridium-platinum. Johnson Matthey was deeply concerned with this work and since then has regularly supplied further national prototypes and working standards to a strict specification.

Amid the turmoil of the French Revolution a group of some of the most prominent scientists of the eighteenth century achieved one major positive step—the foundation of a new unified system of weights and measures, now known to us as the metric system. Lavoisier, while a member of the Provincial Assembly of Orléanais, had advocated the introduction of such a system to replace the confusion of separate provincial systems of weights and measures then prevailing in France (1). When he became a member of the Third Estate in the States-General of 1789 he found his views reflected widely and the National Assembly adopted a proposal by Talleyrand that the Academy of Sciences should set up a Commission to formulate the unified system.

All the members of this Commission were eminent French scientists but the most important worker on this project was Lavoisier himself. Antoine Laurent Lavoisier was born in 1743 and showed an early interest in matters of a scientific nature. After studying at the University of Paris he undertook mineralogical and chemical researches for the French Government, for example in the improvement of gunpowder manufacture. His chemical work has led to him being described as "the father of chemistry". He also held a position in the tax-farming structure, which ultimately brought him to his death during the Revolution.

The members of the Commission were Laplace, Lagrange, Borda, Monge, and Condorcet. Lavoisier was appointed as

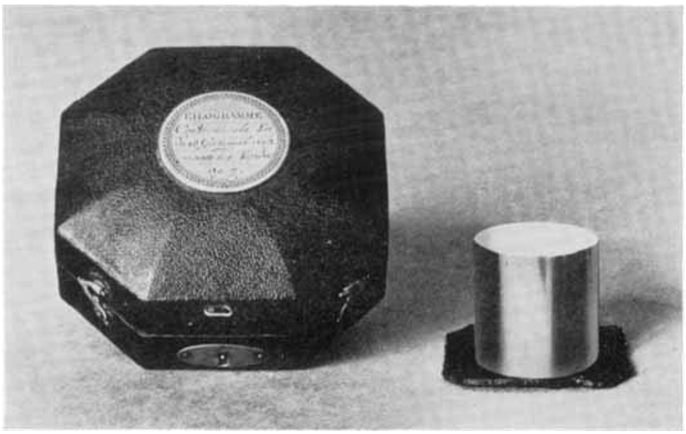

Fig. 1 This standard kilogram was made by Janety using platinum. The label on the case states "Kilogramme Conforme ala Loi du 18 Germinal An 3 [April 7th, 1795], présenté le 4 Messidor An 7" [June 23rd, 1799]

Fig. 2 A group of three standard 10 per cent iridium-platinum kilograms fabricated by Johnson Matthey Metals for the Bureau International des Poids et Mesures. The purity of the alloy and the dimensions and density of the cylinders are controlled to a rigorous specification. Diameter is made 39.2 mm, height 39.5 mm and density 21.53 g/cm³

secretary to the Commission and also worked with Hauy to determine the weight of one cubic centimetre of distilled water, to be known as the gram. The centimetre was, of course, one hundredth part of a metre, the latter being defined as 1/10,000,000 part of the meridian quadrant passing through Paris. The work on the gram took place in Lavoisier's laboratory at the Paris Arsenal but it was interrupted by the dissolution of the Academy. Lavoisier himself was guillotined by the Revolutionary Tribunal in May 1794 but work had progressed sufficiently for prototype standards to be constructed from 1795 onwards. The metric system was finally confirmed in 1799 while Napoleon was First Consul.

The most convenient standard of weight proved to be the kilogram, defined as equal to the mass of one cubic decimetre of distilled water at its maximum density, which occurs at 4°C. The material form of the standard kilogram took the shape of a platinum cylinder of height equal to its diameter. The first material prototype standards of the metric system were fabricated by Marc Etienne Janety, who was recalled to Paris to undertake the work from Marseilles, whither he had gone to take refuge from the Terror, as he had been a court goldsmith. The prototypes were called the Mètre and Kilogramme des Archives. Janety fashioned several platinum standard metres and kilograms from about 1795 (2, 3) and one of the latter is illustrated in Fig. 1.

Bureau International des Poids et Mesures

During the nineteenth century it was shown that the volume of a kilogram of water derived from the first standard platinum kilogram was 1.000028 dm³ at standard conditions, i.e. there had been an error of 28 parts in one million during fabrication of the man-made standard kilogram. This serious discrepancy illustrates the early difficulty in preparing accurate standards. It thus became necessary to revise and improve the standards.

In 1870 as a result of the need for worldwide unification of measures the French government arranged a conference of representatives from 24 countries to consider such matters. This led to the Convention du Mètre and on May 20th, 1875, 28 countries agreed to set up the Bureau International des Poids et Mesures at Sèvres, a suburb of Paris. The first mission of the Bureau was to construct and maintain international prototypes of the metre and the kilogram, and to furnish copies of these standards to the various countries party to the convention.

The new standards were made by the Bureau as near as possible to the values of the Mètre and Kilogramme des Archives. The alloy chosen for their fabrication was 10 per cent iridium-platinum because of its stability, hardness, high density, and resistance to corrosion. It remains the specified material to this day.

The firm of Johnson, Matthey & Co was concerned intimately in this work (4). Already George Matthey had supplied Russian metal for standards and had assisted in its refining, melting and casting into ingots from which standards were produced in 1874. Now further orders followed with fabrication taking place in 1878 and 1879. Then agreements made in 1882 with the French government led to Johnson, Matthey & Co producing 30 standard metres and 40 standard kilograms, all in the 10 per cent iridium-platinum alloy.

The First General Conference of Weights and Measures was held in September 1889 and approved the new standards. The kilogram was redefined arbitrarily in terms of the new International Prototype Kilogram so that our present standard of mass has a permanence dependent only upon the stability of the iridium-platinum alloy. The International Prototype Kilogram is a 10 per cent iridium-platinum cylinder with diameter and height both equal to 39 mm. The national prototype kilograms in each state standardising laboratory are intercompared periodically with the working standards of the Bureau but to prevent damage and to avoid the risk of any minute change of mass the International Prototype Kilogram itself has been intercompared with other prototypes only once, in 1946, since its acceptance in 1889. State standardising laboratories determine the mass of their working standards against their national prototypes as mass references.

Production of Kilogram Cylinders

From time to time further national prototypes and working standards are required. The Johnson Matthey Group has been called upon regularly to supply them. A group of three such cylinders is shown in Fig. 2 and was produced recently by Johnson Matthey Metals Limited for the Bureau.

The specification for kilogram cylinders is very strict. It calls for an alloy composed of 89.75–90.25 per cent platinum and 9.75–10.25 iridium. The maximum proportion of metallic impurities allowed is 0.1 per cent ruthenium, 0.1 per cent iron, 0.15 per cent rhodium and palladium together, and 0.02 per cent all other metals together. Each cylinder is to be 39.2 mm diameter, 39.5 mm high and of minimum mass 1020 g as supplied. There must be no apparent surface defects and the alloy must be free of internal porosity or cracks. The density must be not less than 21.53 g/cm^3 at 0°C.

Rigorous testing for defects is carried out by Johnson Matthey Metals before the cylinders are despatched to the Bureau, which carries out the final stages of comparison, applying the final adjustments necessary to give the extreme degree of precision of all kilogram standards in service.

References

1 D. McKie, "Antoine Lavoisier", Constable, London, 1952, 335 pp.
2 D. McDonald, "A History of Platinum", Johnson Matthey, 1960, 127–129
3 D. McDonald, *Platinum Metals Rev.*, 1968, 12, (4), 142–145
4 D. McDonald, "A History of Platinum", Johnson Matthey, 1960, 207–213