ON THE SCIENCE OF WEIGHING AND MEASURING, AND THE STANDARDS OF WEIGHT AND MEASURE *

VI.

At the time when the metric system was originated, the French standards of weights were the series known as the *Pile de Charlemagne*, the unit being the *Livre poids de marc* of 16 *onces*, and double the *poids de marc*. The metric equivalent of the *poid de marc* was subsequently determined to be 244·753 grammes. The *once* was divided into 8 *gros* (or drachms), and the *gros* into 72 *grains*. The old French *Livre* of 9216 French *grains* was therefore equal to 489·506 grammes, and 7554 English troy grains. The French *grain* was thus equal to 0·818 English troy grain. In determining the new unit of metric weight, it was necessary to ascertain the actual value in terms of the existing system of the *livre* and its subdivisions, of the provisional weights used; and from accurately comparing them with the old standards, it was deduced from the ascertained weight of the measured cylinder, that the weight of a cubic decimetre of distilled water at its maximum density, or at 4° C., which was 0·9992072 of the provisional kilogram, was equal to 18827·15 grains of the *poids de marc*. This, accordingly, was definitively adopted as the true weight of the kilogram, the new unit of metric weight.

The determination by the French Commission of the weight of a cubic decimetre of water at its maximum density differs somewhat from later authoritative determinations made in England and other countries, as may be seen from the following tabular statement:—

Date.	Country.	Observer.	Weight of cubic decimetre of distilled water at 4° C.
			Grammes.
1795	France .	Lefevre-Gineau . . .	1000·000
1797 & 1821	England	Shuckburgh and Kater	1000·480
1825	Sweden .	Berzelius, Svanberg, and Akermann . .	1000·296
1830	Austria .	Stampfer	999·653
1841	Russia .	Kupffer	999·989
		Mean	1000·084

But the latest and most carefully executed determination by Kupffer agrees so closely with the French determination, that the actual weight of the primary kilogram may be taken as nearly identical with its theoretical definition, and sufficiently accurate for all practical purposes.

From the provisional brass kilogram, with its error thus ascertained by the French Commission, two new standard kilograms were constructed by Fortin, one of platinum, the other of brass, and each was determined, after numerous comparisons and the requisite corrections, to be of the true weight when weighed in a vacuum. The platinum weight was constituted the primary metric standard kilogram, and is known as the *Kilogramme des Archives*. Its form is that of a cylinder of about 39·4 millimetres in diameter, and 39·7 metres high, having its edges slightly rounded, being similar to that of the English platinum kilogram shown of the actual size in Fig. 12. The density of the *Kilogramme des Archives* has never been precisely determined, as it has been deemed hazardous to weigh it in water from a fear of its not being entirely free from the arsenic used in preparing the platinum, and of dissolving this arsenic, and thus diminishing the weight of the kilogram. Prof. Miller has assumed the volume of the *Kilogramme des Archives* when in its normal temperature of 0° C to be equal to the volume of 48·665 grammes of water at its maximum density, as determined by its cubic measurement, and consequently its density to be 20·5487. Other computations, however, differ slightly from this determination.

The brass kilogram was intended as the commercial standard, for regulating all ordinary metric weights in air, and was deposited at the Ministère de l'Intérieure Paris. One uniform shape is adopted in France for all brass kilograms. They are made in the form of a cylinder surmounted with a knob. The height of the cylinder is equal to its diameter, and the height and diameter of the knobs are equal to one half those of the cylinder. Like the platinum *Kilogramme des Archives*, the brass standard kilogram was never weighed in water, and its volume has been computed from its cubic measurement to be equal to that of 124·590 grammes of water at its maximum density, thus making its density 8·206. In our standard air, $t = 62°$ F. $b = 30$ in., the platinum standard kilogram will thus displace 59·25 milligrams of air, and the brass kilogram 151·75 mgr.; the apparent weight in air of the brass kilogram is consequently about 92 mgr. less than that of the platinum standard. This brass kilogram was assumed by the French Commission to be 88·5 mgr. lighter than the platinum standard, when weighed in ordinary air.

The primary platinum metre and kilogram were presented by the Commission on June 22, 1799 to the Corps Legislatif at Paris, and were legally constituted as the standards of length and weight of the new metric system throughout France by the law of Dec. 9, 1799. They were deposited at the Palais des Archives.

A platinum copy of each of the primary metric standards of the metre and kilogram was constructed at the same time, and deposited at the Paris Observatory. These standards, known as the *Mètre de l'Observatoire*, and the *Kilogramme de l'Observatoire*, were considered as next in authority to the primary standards.

The unit of capacity of the metric system, the *litre*, represents theoretically the measure of volume of a cubic decimetre, or the cubic contents of a metallic vessel of this capacity when at the temperature of melting ice. But practically, there is no material primary standard litre, and the legal measure of the litre is determined from the kilogram; that is to say, the litre actually is a measure containing a kilogram weight of distilled water at its maximum density. Such a measure can only be verified by computation, as the vessel itself must be taken at a different temperature from the water contained in it, the vessel at 0° C., the water at 4° C. Authoritative tables are therefore prepared for ascertaining the allowance to be made in every case for differences of temperature from the normal temperature, as well as for the difference of weight of air displaced by the metallic weight and the larger volume of water.

For metric measures of surface, the *are*, equal to 100 square metres in the unit; and for solid measures, more particularly for measuring wood, the *stere*, or cubic metre, is the unit.

The number and denominations of the metric weights and measures actually used in France and other countries, for which specific standards are provided, are as follows: they include the double and the half of each decimal unit, with a duplicate unit to make up the number 9 units:—

6 Metric Measures of Length:
- Double metre
- Metre, divided into tenths or decimetres, &c.
- Half-metre, " "
- Double decimetre, divided into centimetres and millimetres
- Decimetre, " "
- (For land) Chain of double dekametre, or 20 metres, divided into metres, and links of 2 decimetres

* Continued from p. 389.

30 Metric Weights	20, 10, 5, 2, 1, 1 kilograms
	500, 200, 100, 100 grammes (hectograms)
	50, 20, 10, 10 „ (dekagrams)
	5, 2, 1, 1 „
	0·5, 0·2, 0·1, 0·1 gramme (decigrams)
	0·05, 0·02, 0·01, 0·01 „ (centigrams)
	0·005, 0·002, 0·001, 0·001 gramme (milligrams)

13 Metric Measures of Capacity	Hectolitre,	or	100	litres
	Demi-hectolitre,	„	50	„
	Double dekalitre,	„	20	„
	Dekalitre,	„	10	„
	Demi-dekalitre,	„	5	„
	Double litre,	„	2	„
	Litre,	„	1	litre
	Demi-litre,	„	0·5	„
	Double decilitre,	„	0·2	„
	Decilitre,	„	0·1	„
	Demi-decilitre,	„	0·05	„
	Double centilitre,	„	0·02	„
	Centilitre,	„	0·01	„

Total number of metric weights and measures used in France and other countries, 49.

For dry commodities, the demi-dekalitre is the smallest measure used. The litre being equal to a cubic decimetre, or 1,000 cubic centimetres, in volume, is also equal to 1,000 grammes weight of distilled water at its maximum density; consequently the

Demilitre	= 500 cubic centimetres, or grammes weight of water.		
Double decilitre	= 200	„	„
Decilitre	= 100	„	„
Demi-decilitre	= 50	„	„
Double centilitre	= 20	„	„
Centilitre	= 10	„	„

There are also graduated measures of 5, 2, and 1 cubic centimetres or grammes weight of water.

The earliest recognition by the British Parliament of the metric system thus established in France took place soon after the close of the war. On March 15, 1816, Mr. Davies brought forward a motion in the House of Commons, which was carried, for comparing the imperial standard yard with the French standard metre. The Government entrusted the necessary operations to the Royal Society, who obtained for the purpose two platinum metres from Paris. These had been verified by M. Arago, by comparison with the French standard. One was an end-standard, like the "Metre des Archives," but was nearly twice as thick, being 7·3 milimetres in thickness.

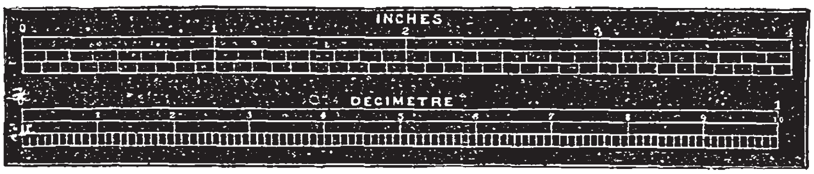

FIG. 11.—Decimetre and its nearly equivalent length of four inches

On one plane surface the word "METRE" is engraved, and on the other "FORTIN A PARIS," and "Royal Society, 44." This end-standard was determined to be exactly the length of a metre at the temperature of melting ice. The other was a line standard, the bar being nearly equal in width, but only 5·3 millimetres thick, and it is about 4 centimetres longer. On the upper surface is engraved "Royal Society, 45," and transverse lines, so fine as hardly to be seen with the naked eye, are cut about 2 centimetres from each end for defining the length of the metre, as shown in the following figure:—

The length of a metre is to be taken between the two transverse lines at the mid-width of the bar, and it has been determined to be less than a metre by 0·01759 millimetre, taken at the standard temperature of melting ice.

On being brought to this country, the two platinum metres were carefully compared by Captain Kater with the length of 39·4 inches on the Shuckburgh scale, considered by him to be the British scientific standard of length. Full details of the comparisons made with Captain Kater's microscopical comparing apparatus are given in Phil. Trans. 1818. It was required to determine the length of the platinum metre at its standard temperature of 32° Fahr. in terms of the brass standard yard of 36 inches at its standard temperature of 62° Fahr. Allowance was made for the different rates of expansion of the two metals, the co-efficient of expansion of the platinum being taken to be 0·00000476 for 1° Fahr., as determined by Borda, and that of brass 0·0000101, as found by Kater's experiments. The length of the metre at 32° Fahr. was thus determined from the *mètre à bouts* to be 39·37086 inches of the Shuckburgh scale at 62° Fahr., and from the *mètre à traits* 39·37081 inches, after allowing for its error = 0·00069 inch. The mean length of the metre was therefore 37·37084 inches of the Shuckburgh scale, and as this scale had been found 0·00005 inch longer than the Parliamentary standard, the true length of the metre was finally determined by Captain Kater to be 39·39079 British inches.

Ever since this period, this authoritative equivalent of the metre in imperial measure has been recognised as the true equivalent, and it received the sanction of Parliament, in the Act of 1864, for legalising contracts made in this country in terms of the metric system. It is, however, to be observed that it is the *scientific* equivalent of the metre in imperial measure. For all *commercial* purposes, on the other hand, the measure of a metre is always used at ordinary temperatures just as a yard measure is used, and the comparison of the two should therefore be more properly made at the same average temperature of 62° F. At such temperature a brass metre is equal to 39·382 inches, and this length is to be taken as the commercial equivalent of the metre in British measure. Of course, this difference of the equivalent in imperial measure of the metre at its legal and at its ordinary temperature, amounting only to $\frac{3}{1000}$ inch is perfectly immaterial in commercial measurements of small quantities, and the metre may safely be estimated as equal to $39\frac{3}{8}$ of our inches, and the decimetre at 3·94 inches, as shown in Fig. 11.

No satisfactory comparison of the primary kilogram with our unit of imperial weight was made until the year 1844, after the construction of the new imperial standard pound, under the authority of the Standards Commission. The comparison of the standard units of weight of the two countries was then undertaken by Prof. Miller, at the request of the Commission. He found that previous determinations of the weight of the kilogram varied amongst themselves from a minimum of 15432·295 gr. to a maximum of 15438·355 grains. Under these circumstances, he proceeded to Paris in the autumn of 1844, and obtained permission from the French Government to compare the Kilogramme des Archives with our English weights. For the comparison, he took with him the Parliamentary copies Nos. 1 and 2 of the standard pound, and two auxiliary platinum weights together, equal to about 1432·35 grains. The mean result of 60 comparisons was to find the Kilogramme des Archives epual to 15432·34813 grains. But Prof. Miller was not satisfied with this result, as one of the auxiliary weights was found to contain a small cavity filled with some hygroscopic substance, which rendered its weight slightly variable.

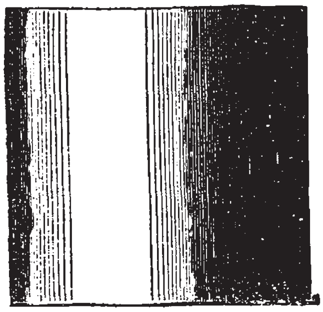

FIG. 12.—Platinum Kilogram 𝕮.

He therefore considered it requisite to make further comparisons directly with the English standard pound.

For this purpose, a platinum kilogram, constructed by Gambey, was procured at Paris by Prof. Miller, and was accurately compared by him with the Kilogramme des Archives. This platinum kilogram, designated as 𝕮 by Prof. Miller, is similar in form to the prototype, but is a little smaller, in consequence of the somewhat greater density of the platinum of which it is composed. Its

FIG. 13.—Gilt Gun-metal Kilogram 𝕽.

density was determined by hydrostatic weighings to be 21·13791. From the mean of 100 direct comparisons with the Kilogramme des Archives, 𝕮 was found to be lighter in a vacuum than the French standard by 1·56 mgr. (0·02412 gr.). For ascertaining the weight of 𝕮 in terms of the new imperial standard pound, Prof. Miller subsequently compared this kilogram with the imperial standard pound, together with each of its Parliamentary copies successively, and one of four auxiliary platinum weights, each of 1432·324 grains, constructed for the purpose, and accurately verified in terms of the imperial standard, by means of supplementary platinum weights. The mean result of 166 direct comparisons of 𝕮 was to find its value = 15432·32462 grains. The Kilogramme des Archives was consequently determined to be equal in a vacuum to 15432·34874 imperial grains, or 2·20462125 standard platinum lb.; and the imperial standard pound equal to 453·5926525 metric grammes. These equivalents have since been generally accepted, and were legalised in this country by the Metric Act, 1864.

The platinum kilogram 𝕮 has since been deposited in the Standards Department, together with a second kilogram, of gilt gun metal, also made under Prof. Miller's directions, and intended as a standard for the adjustment of commercial metric weights, like the French *kilogramme laiton* deposited at the Ministère de l'Intérieure at Paris. This gilt gun metal kilogram was constructed by Oertling and has been denoted as 𝕽 by Prof. Miller. Its form is spherical with a knob. Its density is 8·3291°. The mean result of 24 comparisons with 𝕮 showed that in a vacuum the weight of 𝕽 was 1·47 mgr. less than 𝕮, and 3·04 mgr. less than the Kilogramme des Archives. In standard air (t. = 18°·7 C., b. = 755·64 mm.) 𝕽 displaced 143·92 mgr. and the Kilogramme des Archives 58·36 mgr. 𝕽 was then found to be 88·6 mgr. lighter in air than the French platinum prototype, and only 0·06 mgr. lighter than the French commercial brass standard kilogram.

Although the metric system was established in France as the legal system of weights and measures in 1799, it was not until more stringent provisions of law for enforcing its exclusive use were passed in 1837, that metric weights and measures began to be generally adopted in that country. Since that period it has been gradually adopted in other countries, and there is now every prospect of its finally becoming universally in use, and being acknowledged as an international system of weights and measures. Attention has been already drawn in NATURE, vol. vii. p. 197, to the proceedings of the International Metric Commission at Paris for the construction of uniform metric standards for all countries who have adopted or contemplated the adoption of the metric system, as well as to the material, an alloy of platinum and iridium, adopted for the new standards, and the peculiar form of the new International standard metre. It will therefore be sufficient here merely to show the adopted form of the new standard metres, as compared with that of the existing Standard Metre des Archives, in the following figures, all of the actual size:

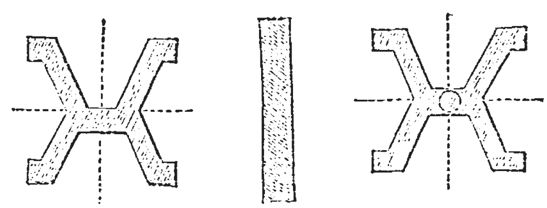

FIG. 14.—Form of New Standard Metres.

The form of the new International kilogram will be the same as that of the Kilogramme des Archives, a cylinder of equal diameter and height, with the edges slightly rounded, as already described.

H. W. CHISHOLM

(*To be continued.*)

NOTES

A LETTER has been addressed by Dr. Anton Dohrn to the Colleges, and other bodies of the University of Oxford, giving an account of the cost, extent, and purposes of his zoological establishment at Naples, pointing out the incalculable advantages