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

II.

It has already been mentioned that the gravitation or weight of bodies varies with their density, and the density of the medium in which they are placed. In order to ascertain the true relative weight, as well as the actual weight of standard weights differing in density when they are weighed in air, it is necessary to allow for the weight of air displaced by each. It thus becomes necessary to reduce these weighings to a vacuum, *by deducting from the apparent weight in air the weight of the volume of air displaced by each standard.*

But the weight of a given volume of air is necessarily more or less according to its temperature, the pressure of the atmosphere, and other conditions affecting it; and

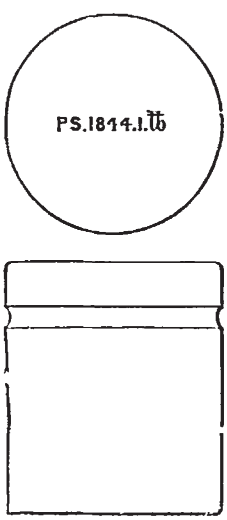

Fig. 1.—Imperial Standard Pound of Platinum. Diameter = 1·15 inch. Δ = 21·1572. Displaces 0·403 grains of air.

Upper Surface of Platinum Standard Pound shown.

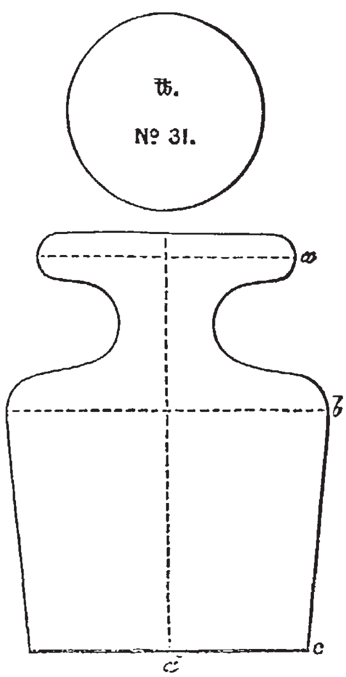

Fig. 2.—Official Standard Pound, Gilt Gun Metal. No. 31.
Size: Diameter at a = 1·25 inch.
„ b = 1·65 „
„ base c = 1·47 „
Height d = 2·2 inches.
Δ = 8·5144
Displaces 1·001 grain of air.

Upper Surface of Gilt Gun Metal Standard Pound shown.

the following data are requisite for ascertaining the weight of air displaced by each standard.

1. The mean temperature of the air during the weighings.
2. The mean barometric pressure reduced to 32° Fahr. and corrected for the pressure of vapour and of carbonic acid gas in the air.
3. The density of the metal of which each standard weight is composed.
4. The co-efficients of expansion of the metals and of air.
5. The relative weight of each standard.

From data 1 and 2 the ratio of the density of the air to the maximum density of water must be ascertained. This ratio is also affected by the height above the mean level of the sea, and the latitude of the place where the comparison is made, as the force of gravity differs accordingly. But in practice the determination of the weight of air displaced in weighing is easily and quickly effected, either by the more accurate mode of making the computations from the above-mentioned data, with the aid of a logarithmetical formula and tables for reduction of weighings, or approximately by special tables showing the mean weight of ordinary air displaced by standards of various densities. The mean ordinary air taken as the standard air in this country is of the normal temperature of 62° Fahr., the barometer being at 30 inches, with the mercury reduced by computation to the temperature of 32° Fahr., the amount of aqueous vapour in the air being assumed to be two-thirds of the quantity in saturated air, and the amount of carbonic acid contained in it being taken at 0·0004 of its volume.

* Continued from p. 270.

The actual mode of ascertaining the weight of air displaced by standard weights when compared by weighings in air, will be described more at length afterwards. But some illustrations may here be given of the effect of the difference of density in standard weights, upon their weight in ordinary air. The following 1lb. avoirdupois weights are of the actual form and size:—

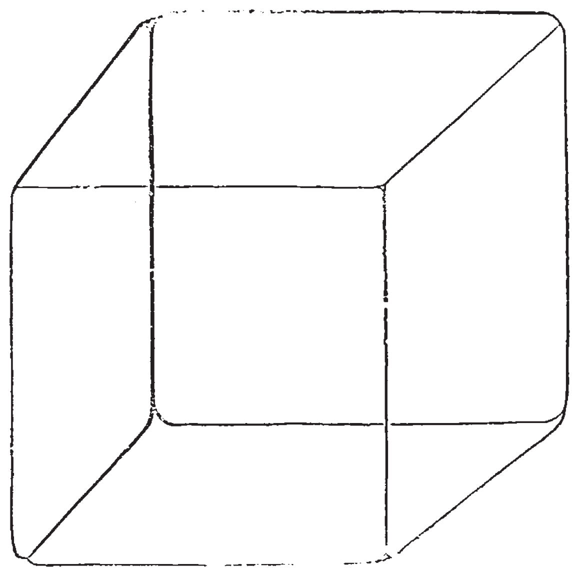

Fig. 3.—Quartz Pound in Standards Department, bearing no mark. Size = 2·17 inches cube, edges rounded. Δ = 2·6505. Displaces 3·216 grains of air.

It may here be seen that the difference of air displaced by the imperial standard lb. P.S. (Fig. 1), and the gilt gun metal lb. No. 31 (Fig. 2), is 0·598 gr.; and if they were equal in weight when in a vacuum, No. 31 would be 0·598 gr. lighter in air of the given density. No. 31 is one of the gilt gun-metal secondary standard weights, intended to regulate the weighings in air of all commercial weights. As the primary platinum standard P.S. from its greater density displaced so much less air than ordinary brass and iron weights—the density of cast-iron being about 7·408, and a cast-iron lb. displacing about 1·150 gr. of air—the weight of all the gilt gun-metal lbs., of which No. 31 was one, was referred by Prof. Miller to a theoretical commercial standard lb. of brass of the average density of brass and bronze weights (Δ = 8. 143), and thus displacing 1·047 gr. of standard air. This commercial standard lb. denoted as W. was assumed to be of the same weight in a vacuum as P.S., and consequently in standard air P.S. was 0·644 gr. heavier than W.

The standard pound of quartz (Fig. 3) displaces 3·217 grains of air. It was constructed as an auxiliary standard on account of the invariability of quartz, and its apparent

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weight in air was made intermediate between that of a pound of platinum and a pound of brass, being 0·401 gr. lighter than P.S., and 0·232 gr. heavier than W. in standard air.

As the determination of the density of bodies has thus been referred to the maximum density of an equal volume of water, it was evidently necessary to determine the absolute weight of a normal measure of water at its maximum density, in order to determine the true weight in air of a given volume of any substance, the density of which has been ascertained. It is claimed to be one of the important advantages of the decimal metric system, that this relation may be at once ascertained from the circumstance of the unit of weight, the kilogram, having been determined by its being the weight of a cubic decimetre of pure water at its maximum density. Thus the volume of any body expressed in cubic decimetres, or the measure of capacity of liquids expressed in litres, the litre being the measure of a vessel holding a cubic decimetre of water at its maximum density, when multiplied by its density, at once gives the weight in kilograms; or, if expressed in centimetres, the weight will be given in grammes. There is not the same simple relation between the unit of weight and of volume or capacity in the imperial system, the same definite ratio not being established between the unit of cubic capacity derived from the unit of length and the unit of weight, which is found in the metric system. This relation has therefore been determined experimentally in England from ascertaining the weight of a cubic inch of pure water, and the determination by Sir George Shuckburgh in 1798 was accepted by scientific men in this country, and has been legalised by Statute, by which a cubic inch of water at the temperature of 62° F. weighed in air of the same temperature, with the barometer at 30 inches, weighs, 252·458 grains of brass. From this ratio, the cubic capacity of the standard gallon, containing 10 lbs. weight of water, is declared to be 277·274 inches, and a cubic foot of water is declared to weigh 62·321 lbs. avoirdupois. But this ratio does not agree with that adopted in France, nor indeed with other and different ratios adopted in Sweden, Austria, and Russia respectively, as determined from separate experiments made in each of these countries. As respects the metric system, even assuming the weight of a cubic decimetre of water to be exactly a kilogram according to its theoretical definition, as to which doubts exist, it is only equal to this weight when the water is at the temperature of about 39° F. or 4° C, and when weighed in a vacuum. When of the ordinary temperature (say 62° F.) and weighed against brass weights in ordinary air (say, the barometer at 30 inches), it would weigh not a kilogram or 1,000 grammes, but about 999·012 grammes, the difference being the loss of weight by the weight of air displaced by a cubic decimetre of water. According to the English ratio, the cubic decimetre of water would weigh in air 999·515 grammes. And if the French ratio were applied to our imperial measures a cubic inch of water would weigh 252·336 grains, the capacity of the gallon would be 277·141 inches, and the cubic foot of water would weigh 62·291 lbs. But in point of fact, a new and authoritative international determination of the weight of a standard unit of water is very much needed, in order that its true weight may be satisfactorily ascertained and uniformly adopted in all countries.

II.—*Standards of Imperial Weight and Measure*]

The English standard units of weight and length, the pound and the yard, have come down to us from the Saxons. The Mint pound of the Tower of London, which continued to be the legal unit of weight up to the time of Henry VIII., was the old pound of the Saxon Moneyers in use before the Conquest; whilst the earliest recorded standard of length in this country was the yard or *gird* of the Saxon kings, kept at Winchester. King Edgar is recorded to have decreed, with the consent of his Wites, the standard." No change was made by the Normans in the system of weights and measures established in England, and by a statute of William the Conqueror it was ordained that the measures and weights should be true and stamped in all parts of the country, as had before been established by law.

The old Tower pound was the ancient pound sterling of silver, containing 20*s*., each of 12*d*. or pennyweights. It was also divided into 12 ounces, and was thus used as the apothecaries' weight. The Tower pound was less than the Troy pound by 15 dwt., and contained 5,400 Troy grains. It was discontinued by law in the 24th year of Henry VIII., the Troy pound, which appears to have been first introduced into this country from France at the close of the reign of Edward III., being substituted for it. The mark of 8 ounces was $\frac{2}{3}$ of the Tower pound, and was identical in weight with the ancient unit of money weight in Germany, known as the Cologne Mark. The Tower pound was also nearly identical in weight with the ancient Alexandrian pound, the 125th part of the Great Talent of the Ptolemies, from which it was probably derived. The Troy pound is said to have owed its origin to the Arab *roth* or pound of the Caliph Almamoun, of very nearly equivalent weight, sent as a present to Charlemagne.

The earliest English weight for heavy goods was the merchants' pound, declared in a Statute of Henry III. to be equal to 25*s*., or one-fourth more than the Tower pound. It must thus have been equal to 6,750 Troy grs. Another ancient authority declared the merchants' pound to have contained 15 ounces, and if these were Troy ounces this merchants' pound must have contained 7,200 Troy grs. The merchants' pound seems to have merged insensibly into the avoirdupois pound of 7,000 Troy grs., not later than the time of Edward III. It is certain that commercial pounds nearly equivalent to each of the three weights here specified were largely used in different parts of France and Germany. Our existing avoirdupois pound can be distinctly traced to the time of Edward III.; and there is good ground for believing that no substantial difference has occurred in its weight, or that of the Troy pound, since either of them was first established as a standard in this country.

There can also be little doubt that the length of the English yard has continued unchanged from the earliest times. The standard yard of Henry VII., which is still preserved in the Standards Department, is hardly $\frac{1}{100}$th of an inch shorter than the imperial standard yard, and being an end-standard, it must have lost a little of its original length. The standard weights and measures made in the eleventh year of Henry VII., which are the earliest English standards now known to exist, are all declared to have been taken from the older standards of the Exchequer, as were also the later standards of Queen Elizabeth, which continued to be the legal standards of the country up to the year 1824. Although there is no direct evidence of the origin of the Saxon yard, it is highly probable, from its length agreeing very nearly with that of double the natural cubit (of about 18 English inches) and from its third part, the foot, being very nearly identical with the ancient Egyptian and Greek foot, that these two English unit measures of length owe their origin to the cubit of a man, the earliest known standard measure of length recorded in ancient history.

The Troy pound was the standard unit of weight in this country from the time of Henry VIII. up to the year 1855, when the imperial pound avoirdupois was made the legal standard of weight. The actual primary units of imperial weight and measure are now the standard pound avoirdupois and the standard yard in the custody of the Warden of the Standards, and deposited at the Standards Department, Old Palace Yard, Westminster. They were constructed under the superintendence of the Standards Commission, appointed in 1843 for the restoration of the standards of weight and measure which had been

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or Council, that "the measure of Winchester should be placed in the custody of the Clerk of the House of Commons, and were destroyed by the burning of the Houses of Parliament on October 11, 1834. The members of this Standards Commission had previously given their services as a preliminary committee, having been appointed in 1838 to consider the steps to be taken for restoring the standards, the Act of 1824 (5 Geo. IV. c. 74), under the authority of which the lost standards had been legalised, having directed that, in the event of their loss or destruction, new standards should be constructed in accordance with provisions contained in the Act, by reference to an invariable natural standard.

These provisions were as follows:—In regard to the Standard of Weight, it was recited in § 5 of the Act, that a cubic inch of distilled water, weighed in air against brass weights, at the temperature of 62° Fahr. the barometer being at 30 inches, had been determined by scientific men to be equal to 252·458 grains, of which the Standard Troy pound contained 5,760; and if this Standard were lost or destroyed, a new Standard Troy pound was to be constructed, bearing the same proportion to the weight of a cubic inch of water, as the Standard pound bore to such cubic inch of water.

It will thus be seen that the new unit of weight was declared to be dependent upon the new unit of length, it being based upon the capacity of the cubic inch, or the cube of the thirty-sixth part of the Standard yard.

With respect to the Standard unit of length, § 3 of the Act recited that the Imperial Standard yard, when compared with a pendulum vibrating seconds of mean time in the latitude of London, in a vacuum at the level of the sea, had also been determined to be in the proportion of 36 inches to 39·1393 inches, and it was provided that if lost or destroyed, a new Standard yard should be constructed bearing the same proportion to such pendulum, as the Imperial Standard yard then bore to it.

After long deliberation, the Committee made a very full Report, dated December 21, 1841, and declared their opinion that the several elements of reduction of the pendulum experiments referred to in the Act of 1824, were doubtful or erroneous. It was evident, therefore, that the course prescribed by the Act would not necessarily reproduce the Standard yard. It appeared also that the determination of the weight of a cubic inch of water was still doubtful, differences being found between the best English, French, Austrian, Swedish and Russian determinations amounting to about $\frac{1}{1200}$ of the whole weight, whereas the results of the mere operation of weighing might be determined within $\frac{1}{1000000}$ of the whole weight. The Committee were fully persuaded that with reasonable precautions, it would always be possible to provide for the accurate restoration of Standards by means of material copies which had been compared with them. And they had ascertained that several measures existed which had been most carefully compared with the former Standard yard; and several weights, which had been most accurately compared with the lost Standard pound; and by the use of these, the values of the original standards could be restored without sensible error.

They recommended that no change should be made in the values of the primary units of the weights and measures of the kingdom, or in the meaning of the names by which they were commonly denoted; that the construction of the Standards be entrusted to a Committee of scientific men, under certain instructions contained in the Report, and by comparison with the most carefully selected specimens; that the Parliamentary standard of length be one yard, there appearing no sufficient reason for departing from the length hitherto adopted for the standard; and that the Avoirdupois pound be adopted instead of the Troy pound as the Parliamentary standard of weight, the avoirdupois pound being invariably known and generally used, and the Troy pound being wholly unknown to the great mass of the British population, and comparatively useless. They also recommended that no new specific standard of capacity be established, the unit of capacity, the gallon, being continued to be defined by its containing 10 lbs. weight of distilled water, as specified in the Act of 1824.

Many other important recommendations were also made by the Committee in relation to the official Secondary Standards, and the verification and legalising of local Standards for the use of Inspectors of Weights and Measures throughout the country, and for the Colonies, in order to secure the requisite uniformity in commercial weights and measures, and their accordance with the scientifically constructed primary standards.

For more effectually carrying out these recommendations for the construction of the new Standards, the Standards Commission was appointed on June 20, 1843, and continued their labours until 1854, their definitive Report being dated on March 28 in that year.

The preliminary Committee was composed of the following scientific men:—G. B. Airy, Astronomer Royal, Chairman (now Sir G. B. Airy, K.C.B., and President of the Royal Society); F. Baily, V.P.R.S.; J. E. D. Bethune; Davies Gilbert, V.P.R.S.; J. G. S. Lefevre (now Sir J. G. S. Lefevre, K.C.B.); J. W. Lubbock (afterwards Sir J. W. Lubbock, Bart.); Rev. G. Peacock, F.R.S. Dean of Ely and Lowdian Professor of Astronomy; Rev. R. Sheepshanks, F.R.S.; Sir J. F. H. Herschel, Bart. With the exception of Mr. Davies Gilbert, who died in the meantime, all these scientific men continued their services as members of the Commission for constructing the new Standards. The Marquis of Northampton, P.R.S., Lord Wrottesley, F.R.S., and Prof. W. H. Miller were also appointed members of the Commission. On the death of the Marquis of Northampton, the name of the Earl of Rosse, his successor as President of the Royal Society, was added.

H. W. CHISHOLM

OREODON REMAINS IN THE WOODWARDIAN MUSEUM, CAMBRIDGE

IN addition to the valuable collection of recent skeletons lately given by Lord Walsingham to the University of Cambridge, he also presented a series of mammalian remains from the Miocene deposits of the Mauvaises Terres in Nebraska. These were, fortunately, for the most part brought to England in masses of the original rock, and have therefore had the great advantage of Mr. H. Keeping's care and skill in developing them from the matrix. His long-continued labour has resulted in the most interesting collection of fossils referred to in this notice, and now deposited in the Woodwardian Museum. Professor Hughes has entrusted me with the examination and determination of the remains, and has afforded me every possible assistance. The species revealed, some of which may possibly require the establishment of a new genus, at any rate appear to be new to science, and much larger than any hitherto described in America. We have thought that, pending the preparation of a complete description, your readers would be interested in a general account of the fossils; and especially it has been thought desirable that an account of the skull and dentition should be given in as simple a form as possible; for I have not yet seen any description of the skull other than the complete one of Prof. Leidy. At any rate, fresh interest will be excited in the Oreodontidæ now that so splendid a series of remains can be seen in an English Museum.

A summary of our fossils may be thus given:—

1. A large nearly complete skull, with lower jaw attached; the zygomatic arches being, however, almost destroyed.

2. The greater portion of a large skull preserving very completely one zygomatic arch with posterior crest.

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