

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

IV.

THE IMPERIAL STANDARD YARD

THE immediate superintendence of the construction of the new standard yard was entrusted, in the first instance, to Mr. Baily, who conducted all the preliminary investigations and experiments. After his death in August 1844, it was undertaken by Mr. Sheepshanks, by whom and under whose direction by far the largest proportion of the actual operations was carried out, and all the comparing operations of the several standards of length made, up to the period of his death in August 1855. By this time the work was so far completed that not a single additional comparison of line measures was required. The detailed account of the construction of the new standard yard, and its verified copies, was then undertaken by the Astronomer Royal, with the aid of the documents left by Mr. Baily and Mr. Sheepshanks; and the winding-up of the work of the Commission, and the

distribution of the scientifically verified copies of the standards also devolved upon the Astronomer Royal, as the chairman. The magnitude of the operations may be estimated from the fact of the number of micrometer readings for all the comparisons exceeding two hundred thousand; and amongst the operations it was found necessary to construct an entirely new system of thermometers. It should not be forgotten that the scientific gentlemen who bestowed so much of their valuable time, attention, and labour, during several years upon the experiments and observations for the important object of the restoration of the national standard of length, declined to accept any pecuniary remuneration.

The length of the new standard yard was determined in a similar manner to the determination of the weight of the new standard pound, by taking the mean length of the most authoritative standards which constituted the best primary evidence of the lost standard yard.

This standard measure of length had been constructed by Bird, in 1760, under the directions of the Committee of the House of Commons on Weights and Measures, first appointed in 1758. Its length was taken from a similar yard which had been constructed by Bird in 1758.



FIG. 8.—Standard Winchester Bushel of Henry VII $\frac{1}{2}$ size.

Each of these standard yards consisted of a solid brass bar 1.05 inch square in section, and 39.73 inches long. Near each end of the upper surface gold pins or studs 0.1 inch in diameter were inserted, and points or dots were marked upon the gold to determine the length of the yard. The comparing apparatus in use at that period consisted of a beam compass with two fine measuring points, which could be adjusted to the dots on the standard measures under comparison. But the result of numerous comparisons of this kind made from time to time previously to the destruction of the standard in 1834, had been to leave the edges of the holes indented and irregularly worn away, so that the original centre was very difficult to ascertain. Mr. Baily, who had made some comparisons with this standard yard in the early part of the year 1834, describes the holes as appearing, under a microscope, like the miniature crater of a volcano.

The length of the standard yard of 1758, had been based upon that of the then existing Exchequer standard yard, which had been constructed in the reign of Queen Elizabeth in 1588, and upon the length of the Royal Society's standard yard, constructed as a scientific standard measure in 1742. It had been determined, upon

* Continued from p. 349.

comparison, to agree as nearly as possible with these two authoritative measures of a yard.

The two standard bars of 1758 and 1760 were found amongst the ruins of the Houses of Parliament, but they were too much injured to indicate the measure of a yard which had been marked upon them.

Bird's standard yard of 1760 had been left in the custody of the clerk of the House of Commons, and no legal authority was given to it as a standard of length until the passing of the Act 5 Geo. IV. C. 74, in 1824, already referred to. Meanwhile, other scientific standards of length had been constructed which may now be noticed.

In 1785, the first geodesical operations were begun, upon which the Ordnance Survey of the United Kingdom has since been founded, by General Roy's measurement of the base on Hounslow Heath. The standard used in the first instance for that purpose was that known as General Roy's scale, 42 inches in length, and constructed by Mr. Bird. This scale was based, not on the legal Exchequer Standard, but upon the Royal Society's scale, with which the whole length of the first 36 inches of General Roy's scale was compared, this constituting the *Ordnance yard*. Two standard yards of superior construction, belonging to the Ordnance Department, were placed at the disposal of the Standards Commission.

The test bar of this alloy, when loaded at the centre with $5\frac{1}{2}$ cwt., broke without bending.

4. The form of the standard to be a solid bar 38 in. long, and 1 in. square in section. The measure of a yard to be defined by the distance between two fine lines perpendicular to the axis of the bar, marked upon gold-studs at the bottom of cylindrical holes drilled from the upper surface to the mid-depth of the bar.

The gun-metal, or bronze, thus adopted for the new standard, has since been known as "Baily's metal," and this designation is engraved upon the Imperial standard yard.

In order to select the most perfect specimen for the new standard of length, 40 line-standard yards were constructed of Baily's metal, and one of these was finally selected as the Imperial standard, not only from its representing, with the greatest precision, the assumed length of the lost standard yard, but also from the clearness of its defining lines, and from its general good workmanship. Four of the remaining yards nearest in length to the new standard were selected as Parliamentary copies, and deposited in the same places as the Parliamentary copies of the standard pound already mentioned; and the rest were in like manner distributed amongst different countries and public institutions in this country.

Several other similar line-standard yards were also constructed for experimental purposes, being accurately verified by Mr. Sheepshanks, and were disposed of in like manner, viz.

The defining terminations of these end-bars consist of a plug of agate, slightly conical and shrunk into a similar conical hole at each end of the middle axis of the bar. The ends of the bars are ground and polished in a spherical form, the centre of the spherical surface being the middle of the bar.

All the numerous comparisons of the standard yards were made by Mr. Sheepshanks in one of the lower cellars at Somerset House, under the apartments of the Royal Astronomical Society, where the new micro-metrical comparing apparatus constructed for the purpose by Messrs. Troughton and Simms, was fixed.

A full description of the comparing apparatus will be given under head V. of Weighing and Measuring Instruments, and their Use.

The Commission for restoration of the standards having terminated their labours; recommended in their final report that the new imperial standards of the yard and pound be deposited at the Exchequer Office, there to be preserved under such regulations as to Parliament might appear fitting. In expressing their adherence to the recommendation of the Committee of 1841 that no reference should be made to natural elements for the values represented by the standards of weight and measure, they also recommended that so much of the Act 5 Geo. IV. c. 74, as provided for the restoration of the standards in the manner therein provided be repealed, and that the standards should in no way be defined by reference to any natural basis, such as the length of a degree of the meridian on the earth's surface in an assigned latitude, or the length of a pendulum vibrating seconds in a specified place. They considered the ascertaining of the earth's dimensions and the length of the seconds pendulum in terms of the standard of length, and the determination of the weight of a certain volume of water in terms of the standard of weight, as scientific problems of the highest importance, to the solution of which they trusted that Her Majesty's Government would always give their most liberal assistance, but they did not urge them on the Government as connected with the conservation of standards.

These recommendations were carried into effect by the Act of 1855, 18 and 19 Vict. c. 72, for legalising and preserving the restored standards of length and weight, sec. 1 of which repealed the provisions of the Act of 1824

concerning the restoration of the standards by reference to the pendulum and to the weight of a cubic inch of water.

Under the provisions of the Act of 1855, the imperial standards were deposited in 1855, in the office of the Exchequer. On the consolidation of the ancient Office of the Exchequer with the Audit Office in 1866, and the creation of the Standards Department of the Board of Trade, under the Standards Act, 1866, 29 and 30 Vict. c. 82, the custody of the imperial standards was transferred to the Warden of the Standards, the head of the new Standards Department, and the imperial standards are now deposited in a fireproof iron chest in the strong room in the basement of the Standards Office, which has been specially adapted for their safe preservation. Provision is contained in the Act for the comparison once in every ten years of the three Parliamentary copies of the imperial standards deposited at the Royal Mint, in charge of the Royal Society, and in the Royal Observatory, Greenwich, respectively, with the imperial standards of length and weight, and with each other. Under this Act new scientific duties were also imposed upon the Standards Department, the Warden of the Standards being charged with conducting all such comparisons, verifications, and other operations with reference to standards of length, weight, or capacity, in aid of scientific researches or otherwise, as may be required.

In connection with the question of the derivation of a standard unit of length from a natural constant to be found in the ascertained dimensions of the earth, it may be added that Sir John Herschel has pointed out the fact of the length of the polar axis having been determined, from the combined results of all the scientific measurements of arcs of the meridian, to be equal to 500,482,296 inches of our imperial standard yard, and that if one five-hundred-millionth part of the polar axis were adopted as a new standard unit, to be called the "geometrical inch," it would differ from the imperial inch less than one-thousandth part of an inch; a difference so small as not to be measured by any ordinary method, and only by the aid of the nicest scientific instruments. For all "ordinary practical purposes," the geometrical inch would be identical with the imperial inch; whilst for high scientific measurements for astronomical purposes, it would connect by an unbroken numerical chain the small units with which mortals are conversant in their constructions and operations with the great features of nature, and more especially with those greater units in the measurements of the universe with which astronomy brings us in relation. It would also produce a more exact ratio between our units of length and weight, the avoirdupois ounce being nearly a "geometrical ounce," or one-thousandth part of the weight of a geometrical cubic foot of distilled water. That is to say, whilst the existing legal weight of a cubic foot of distilled water is 997.136 ounces, the weight of a geometrical cubic foot of water would be 998.1 ounces. And as the imperial half-pint is the measure of ten ounces of distilled water, the ratios of these units of length, weight, and capacity would thus be brought within such practical limits of precision as would meet every possible requirement of commercial exigency.

III.—*Derived Units and Multiples and Parts of Imperial Standard Units.*

THE IMPERIAL STANDARD GALLON AND BUSHEL.

With respect to measures of capacity, the sole unit of all imperial measures of capacity, established by the Act of 1824 is the standard gallon, containing 10 lbs. avoirdupois of distilled water, weighed against brass weights in air at the temperature of 62° Fahr., the barometer being at 30 inches. From the imperial standard gallon is derived the imperial bushel of 8 gallons, the standard of capacity for dry goods commonly sold by heaped measure, or incapable of being stricken. Various

units of measures of capacity had been previously established in this country at different periods. In Magna Charta, three such units are recited, "there shall be throughout our realm, one measure of wine, one measure of ale, and one measure of corn." Of these, the most ancient known was the Winchester corn bushel, of the capacity of about 2150.42 cubic inches, together with the Winchester corn gallon of 272½ cubic inches. We have no record of any other standard measures of capacity being actually constructed, until the standard ale gallon of 282 cubic inches was added by Queen Elizabeth, and the standard wine gallon of 231 cubic inches by Queen Anne. All these old standard measures were discontinued as legal measures in 1824, and the new imperial standard gallon of 272.274 cubic inches, and the bushel of 2218.191 cubic inches, constructed and verified under Capt. Kater's superintendence, have since continued to be the standard units of imperial measure for liquids and for dry commodities.

The Exchequer standards of the imperial gallon and bushel formed part of the complete series of secondary standards constructed and accurately verified under Kater's superintendence in 1824. These standards, together with other secondary standards, subsequently legalised, have served for regulating all the commercial weights and measures of Great Britain and her colonies and dependencies from 1824 up to the present time. The Exchequer standards were transferred to the Standards Department of the Board of Trade in pursuance of the Standards Act, 1866.

H. W. CHISHOLM

(To be continued.)

THE FRENCH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE session of this young Association which has just been concluded at Lyons appears to have been altogether successful, and according to the Reports read the Association is in an exceedingly prosperous condition, both as to number of members, income, and the carrying out of the scientific aims which it has in view. The number of members who attended the Lyons Congress was very satisfactory. The capital fund at the end of 1872 was 136,464 francs, and the income for 1873 is expected to be 24,000 francs. One of the aims of the Association is to give an impulse to Science in the provinces, and, as we recorded some time ago, the members of the Association resident about Bordeaux have formed a local association, and it is hoped a similar result will follow in the case of each town where the yearly meetings are held. The Association has received invitations for its next session from various French cities, and it has been decided to hold the meeting of 1874 at Lille. M. Wurtz was elected President for the ensuing year.

The accounts which have come to hand are mainly concerned with the work done in the Medical Section. Last week we gave a few extracts from the Presidential Address of M. De Quatrefages, and shortly we hope to be able to give a *résumé* of the work done in the various sections, as well as of the more important public lectures. Meantime we shall give a brief sketch of the general work which has been done.

In the general meetings, Dr. Blanc, an Indian military surgeon, read an important paper "on the means of arresting the propagation of cholera," founded on experiments made by himself. M. A. Gaudry, Professor at the Jardin des Plantes, Paris, gave a lecture on a botanical subject. Dr. Bertillon also gave a lecture on "Demography," *i.e.* the Natural History of Society. M. de Lesseps talked in a familiar and pleasant way of the proposed railway across Central America. M. F. Papillon read a paper on the connection between

the Sciences and Metaphysics, and the Abbé Ducrost gave a lecture on the Prehistoric Station of Solutré.

The part of the Congress which is undoubtedly the most attractive consists in the excursions and the public lectures; the former interest strangers, and the latter, members. Besides the special excursions organised by certain sections and parties of members, there have been three general excursions—one to the prehistoric station of Solutré; a second to the sides of the plateau of Les Dombes; a third to the mines and furnaces of Voult-sur-Rhône, in Ardèche, and a fourth, which set out last Friday and was to last for two days, to Geneva and the shores of its lake.

There have been three public lectures: the first was given by M. Karl Vogt, of Geneva, on Volcanoes; the second by M. Janssen, on the Physical Constitution of the Sun; and the third by M. Aimé Girard, on the Recent Progress of Industry.

NOTES

THE final arrangements for the Bradford meeting of the British Association are as follows:—The first General Meeting will be held on Wednesday, Sept. 17, at 8 P.M. precisely, when Dr. Carpenter, LL.D., F.R.S., &c., will resign the Chair, and the President-Elect, Prof. W. A. Williamson, F.R.S., will assume the presidency, and deliver an Address. On Thursday evening, Sept. 18, at 8 P.M., a Soiree; on Friday evening, Sept. 19, at 8.30 P.M., a discourse by Prof. W. C. Williamson, F.R.S., of Manchester, on Coal and Coal Plants; on Saturday evening, Sept. 20, a Lecture on Fuel to working men only, by Mr. Siemens, F.R.S.; on Monday evening, Sept. 22, at 8.30 P.M., a Discourse on Molecules, by Prof. Clerk Maxwell, F.R.S.; on Tuesday evening, Sept. 23, at 8 P.M., a Soiree; on Wednesday, Sept. 24, the concluding General Meeting will be held at 2.30 P.M., and in the evening a Grand Concert will be given in St. George's Hall, at 8 P.M. The excursions on Thursday, Sept. 25, will be to Harrogate, Ripon, Studley, Bolton Abbey, Gordale Scarr, Malham, Clapham Caves, Settle Caves, and Ingleboro'. Lists and prices of lodgings, and other general information will be given, on application at the Local Secretaries' Office, Bradford.

It is said that a portion of the immense wealth of the late eccentric Duke of Brunswick is to be devoted to the founding of a Faculty of Medicine in Geneva.

THE King of Prussia has conferred on Prof. Helmholtz the Order of Merit for Science and Art.

THE October number of *Petermann's Mittheilungen* will contain an account of Professor Nordenskiöld's Arctic Expedition during 1872-3, in the direction of Spitzbergen, which has not, geographically, been very successful. The steamer *Solhem* reached Tromsö on August 6, and the following telegram of that date has been received from Prof. Nordenskiöld:—"Just arrived here, all well. My resolution to undertake another ice-journey towards the north after the sledge-journey round North-east-land, has been rendered impracticable through want of provisions, which has compelled us to return. Instead of this we have undertaken extensive deep-sea dredgings as well as botanical, magnetic, and geological researches. I bring with me, besides other from various formations, very important collections of Miocene flora, as well as of two formations which belong to an older geological period hitherto altogether unknown in the Polar regions. These collections throw new light upon the prevailing flora and the climate of former periods, as well as upon the changes which these have undergone."

ACCORDING to the report of the Meteorological Department an earthquake occurred at Nottingham at ten minutes to seven o'clock on Friday morning last.