Northern Boundary Commission, engaged in the survey of the 49th parallel from the Lake of the Woods to the crest of the Rocky Mountains. Archibald Campbell, of Washington, is the commissioner in charge; Major Twining is the chief of engineers on the part of the United States, and Dr. Elliott Coues of the U.S. army is the naturalist of the expedition. The British Government details its proportion of the party, which is thoroughly equipped for this service. The operations of the present year extend westward from Pembina.

The expedition under Major J. Powell, to the cañons of Colorado, is still in the field. Major Powell has spent several years in explorations in this region, and has constructed a map of great interest and accuracy. His ethnological researches among the Piute and other Indian tribes have resulted in a large and exceedingly valuable collection.

Mr. Wm. H. Dall, well known by his elaborate work on the Territory of Alaska, founded on his former three years' residence in that region, is now actively employed in continuing his survey and hydrography in the Aleutian Islands, under the direction of the U.S. Coast Survey, a work on which he has been engaged during the past two years. His labours have been principally in Alaska and the adjacent islands, from which he returned last September, having gone there in the summer of 1871. He spent last winter in San Francisco, in preparing for the expedition of the present year, which included fitting out a vessel expressly for this service. Among other objects contemplated is the selection of an island on the western extremity of the Aleutian chain, to serve for the landing of the Japan cable, for laying which the U.S. steamer *Narragansett* has been detailed to make deep-sea soundings. Mr. Dall is assisted by Prof. Baker, of Ann Arbor, Mich., astronomer.

Mr. Henry W. Elliott is at the head of a private expedition to St. Paul and St. George, the fur-bearing seal islands of Bering's Sea. He has the assistance of Captain Bryant, who is in charge of the U.S. Revenue and other Government interests on these islands. Mr. Elliott is making exhaustive collections in natural history, which he sends to the National Museum at Washington, his investigations respecting seals and walruses being especially valuable and complete. His labours during 1872 were demonstrated by twenty large boxes of collections. He is a very skilful draughtsman, and his drawings of natural subjects are remarkable alike for accuracy and vigour.

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

V.

IV.—*The Metric System*

As a system of weights and measures, constructed on strictly scientific principles, the metric system may justly claim pre-eminence over all others. It was established upon the fundamental basis of the *metre*, its primary unit of length bearing a determinate decimal ratio to one of the largest natural constants, that is to say, the ten-millionth part of the earth's meridian-quadrant. It includes a fixed relation between the units of weight and capacity, the *kilogramme* and the *litre*, and the unit of length, the *metre*, from which both are derived; and it comprehends a uniform decimal scale of multiples and parts of these units. It must, however, be admitted that the more recent progress of modern science has demonstrated that the actual standards of metric length, weight, and capacity do not exactly correspond with their scientific definition; and apart from the insuperable difficulties which have been found to exist in the precise determination of material standards from any natural constant, the unanimous opinion of several of the highest scientific authorities in this country has been deliberately expressed that there is no practical advantage in adopting a unit founded in nature over one of an arbitrary character. In truth, the great advantage of the metric system consists in the simplicity and uniformity of its decimal scale, and the great convenience of this scale for all purposes of account as agreeing with the decimal system of notation, and more especially when combined with a decimal coinage which formed part of the original scheme. These undoubted advantages have proved the chief recommendations to the adoption of the metric system, first by France, and afterwards by so many other countries, and generally in the scientific world. There is now every prospect of the metric system being generally adopted in all countries of the civilised world, thus greatly enhancing its value as a common international system of weights and measures, and constituting, as it were, a universal language for expressing all quantities weighed or measured.

The original steps which led to the establishment of the metric system in France were taken with a view of reforming the old French system of weights and measures, which had become intolerable from their defective state and want of uniformity. In 1790, on the motion of M. Talleyrand, in the National Assembly, the question o the formation of an improved system to be based upon a natural constant, was referred to the French Academy of Sciences. A request was also made at the same time to the British Government that the Royal Society should act jointly with the French Academy, but no response was given to the invitation, in consequence of the distrust then entertained in this country at the progress of the revolutionary party in France. The preliminary work was consequently entrusted to five of the most eminent members of the French Academy, Lagrange, Laplace, Borda, Monge, and Condorcet. The important Report of this Committee, which bears also the signature of a sixth member, Lalande, gave rise to the metric system. It was presented to the Academy on March 19, 1791, and is printed at length in their Memoirs. The choice of the fundamental unit of the new system lay in its derivation either from the length of the seconds-pendulum, of the earth's equator, or of the earth's meridian. The Committee rejected the length of the pendulum beating seconds as the basis of the new standard unit of length, because it involved a heterogeneous element, that of time, as well as an arbitrary element, the division of the day into 86,400 seconds. They proposed a unit of length taken from the dimensions of the earth itself, and not dependent upon any other quantity; and they did not hesitate to select as its basis the quadrant of the meridian in preference to a quadrant of the equator, from its being a universal measure applicable to all countries, as every country was placed under one of the meridians of the earth, whilst only few countries are under the equator. They considered also that no greater dependence could be placed upon the regularity of the equator, than upon the equality or regularity of the several meridians. They recommended the ten-millionth part of the quadrant of the meridian as the definition of the new fundamental unit of length. Renouncing the ordinary subdivision of the meridian-quadrant into degrees, minutes, and seconds, they proposed a uniform decimal scale as practically the best, from its agreeing with the scale of arithmetical notation. In order that no other arbitrary principle should be introduced into the new system of weights and measures, they recommended for the basis of the unit of weight a measured quantity of distilled water, being a homogeneous substance, always to be easily found in the same degree of purity and density; and that such quantity should be weighed in a vacuum at its temperature when passing from a solid to a liquid state.

* Continued from p. 370

For the practical purpose of ascertaining the length of the meridian quadrant, they proposed to measure an arc of the meridian from Dunkirk to Barcelona, a distance of nearly 9½°, and comprehending about 6° to the north and 3½° to the south of the mean parallel of latitude. These extreme points had also the advantage of being both at the sea level. The actual operations required were stated to be as follows:—

1. To determine the difference of latitude between Dunkirk and Barcelona.

2. To re-measure the ancient bases which had served for the measurement of a degree at the latitude of Paris, and for making the map of France.

3. To verify by new observations the series of triangles employed for measuring the meridian, and to prolong them as far as Barcelona.

4. To make observations in lat. 45° for determining the number of vibrations in a day, and in a vacuum at the sea level, of a simple pendulum equal in length when at the temperature of melting ice, to the ten-millionth part of the meridian quadrant, with a view to the possibility of restoring the length of the new standard unit, at any future time, by pendulum observations.

5. To verify carefully and by new experiments the weight in a vacuum of a given volume of distilled water, at the temperature of melting ice.

6. To draw up tables of existing measures of length, surface, and capacity, and of the different weights in use, in order to ascertain their equivalents in the measures and weights of the new system, as soon as they should be determined.

In pursuance of the recommendations of this Report, the law of March 26, 1791, was passed by the National Assembly for constructing the new system upon the proposed basis; and the Academy of Sciences was charged with the direction of the necessary operations. They entrusted the measurement of the arc of the meridian from Dunkirk to Barcelona to two of their members, Méchain and Delambre, who carried on the work during seven years, from 1791 to 1798, notwithstanding many great difficulties and dangers.

The unit of measure adopted for the actual measurement was the existing French standard of length, the Toise of the Academy, better known as the *Toise de Perou*, a measure of 6 French feet (*Pieds du Roi*). This standard is now deposited at the Observatoire at Paris. It is a bar of polished iron, about 1½ inch in breadth, and ⅓ inch in thickness, and a little longer than a toise. The length of a toise is marked by a rectangular step near each end of the bar, leaving the remaining portion at the ends half the thickness of the measuring part of the bar.

The true length of the toise was taken about a line (or $\frac{1}{12}$ inch) above the re-entering angles of the bar, at the temperature of 13° Réaumur, or 16°·25 C. It has been declared to be equal to 76·7563 English inches, the old French foot (which was divided into 12 inches and the inch into 12 lines), being equal to 12·792 English inches. The toise was afterwards found to be equal to 1·94904 metre.

This standard had been originally constructed as the unit for measuring an arc of the meridian in Peru, and for verifying the meridian of Paris, in 1740; and it was substituted in 1766 for the more ancient French standard of length, the *Toise du Grand Chatelet*, from which it had been originally derived. This older toise was deemed wanting in the scientific precision requisite for a standard of length. It had been constructed in 1668, and is said to have been 5 lines shorter than the toise measure then ordinarily used, for which no authoritative standard could be found; and to have been actually derived from the width of the inner gate of the entrance to the Louvre, which, according to the original plan, was made 12 feet wide, and one half of this width was taken for the length of the standard toise.

The measures actually used for the survey operations are known as the *Règles de Borda*. They were four in number, each consisting of a bar of platinum two toises, or 12 French feet, in length, about ½ inch broad, and $\frac{1}{12}$ inch thick. Each platinum bar was fixed at one end only to a bar of brass about 11½ feet long, the other end of the platinum bar being free and extending about 6 inches beyond the corresponding end of the brass bar. The object of this second bar was that it should form, together with the first bar, a metallic thermometer, indicating the temperature of the two bars by their difference of dilatation, which could be measured by a fine vernier. The four measuring bars were accurately verified, and found, when placed together, end to end, not sensibly to differ from eight times the length of the Toise of Peru at the temperature of 12°·5 C.

The base for the measurement of the northern portion of the work was measured at Melun, and found to be 6075·90 toises. The base for the southern portion was measured at Perpignan, and found to be 6006·25 toises.

Meanwhile the Academy of Sciences was abolished in 1793, by a decree of the National Convention, and a Commission of eleven scientific men, consisting principally of those who had been previously engaged in the proceedings, was appointed, in 1795, to carry out all the arrangements for the definitive establishment of the Metric System. In 1798, towards the close of the operations, an equal number of scientific men, representatives of foreign countries, were added to the Commission, which was then composed as follows:—

French Members: MM. Borda, Brisson, Coulomb, Darcet, Delambre, Lagrange, Laplace, Lefevre-Gineau, Legendre, Méchain, de Prony.
From the Batavian Republic: Aeneae, Van Swinden.
Sardinia: Balbo, afterwards replaced by Vassali, from the Provisional Government of Piedmont.
Denmark: Bugge.
Spain: Pédrayés, Ciscar.
Tuscany: Fabbroni.
Roman Republic: Franchini.
Cisalpine Republic: Mascheroni.
Ligurian Republic: Multedo.
Helvetian Republic: Trallès.

The final results of all the operations for determining the new metric unit of length, were stated by the Commission in their Report, dated April 30, 1799. They found:—

1. That the length of the arc of the meridian comprehended between Dunkirk and Barcelona, was 9·6738° (or 9° 40′ 45″), and measured 551,584·72 toises.

2. Assuming, from the previous measurements in France and Peru, that the mean ellipticity of the earth was $\frac{1}{334}$, they computed the length of the meridian-quadrant to be 5,130,740 toises.

3. That the length of the new unit of length, the ten-millionth part of the meridian-quadrant, was equal to 0·5130740740 toise, or 3 feet and 11·296 lines; being 443·296 lines of the Toise of Peru (which contained 864 lines), at its standard temperature of 16°·25 C. In terms of the new standard unit, the Toise of Peru was equal to 1·949036591 metre.

4. That the length of the pendulum at the temperature of melting ice, beating seconds in a vacuum at the sea level at Paris, was equal to 0·99385 metre.

The actual construction of the new standard measure of length had been entrusted to the mechanician Lenoir. As a preliminary proceeding, he made four end-standard metres of brass, differing in length very slightly from each other, and each about equal to 443·242 lines of the Toise of Peru. This was the computed length of one ten-millionth part of the meridian-quadrant, as deduced from the previous measurements of an arc of the meridian in France made in 1740. The length of these four brass metres, when placed end to end, was nearly 1,773 lines, thus exceeding double the length of the Toise of Peru, by about 45 lines. Lenoir constructed a supplementary measure of this excess of length, and its exact relation to the toise was ascertained by numerous comparisons, for which other intermediate measures were employed, and their exact length determined. The actual comparisons of the four brass metres were made not with the Toise of Peru itself, but with two standard toises constructed by Lenoir, the length of each of which in relation to the Toise of Peru had been carefully determined. In these comparisons the additional length of the measure of 45 lines was also employed. The comparing instrument was a *comparateur* made by Lenoir, which enabled very minute differences in measuring bars under comparison to be read off on a subdivided scale by means of a contact lever. One division of this scale was equal to 0·00001 toise, and one-tenth part of one of these divisions (= 0·001949 mm.) could be read off with the aid of a vernier. It appears from the Report of MM. Borda and Brisson, dated July 17, 1795, that the result of a number of comparisons, including those of the four metres with each other, showed metre No. 2 to be nearest to the required length, being 443·4519 lines of the Toise of Peru at the mean temperature during the observations of 12°·96 Réaumur, thus very closely approaching its standard temperature of 13° Réaumur, and exceeding the required length at this temperature by only 0·0119 line. It was accordingly selected as the provisional Standard Metre. But they considered that its standard temperature would more conveniently be fixed at 10° C., and as, according to Borda's determination, the coefficient of dilatation of brass between 0° and 32° C, was 0·00001783 for 1° C. they determined its length at 10° C. to be 443·401 lines of the Toise of Peru.

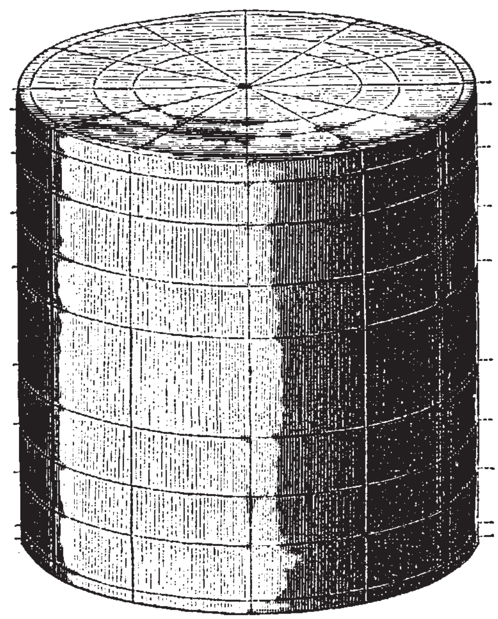
For obtaining the definitive standard, which was to be the length of 443·296 lines of the Toise of Peru at 16°·25 C., which was thus so nearly indicated by the provisional metre, two standard metres of platinum, and twelve metres of iron, were constructed by Lenoir, his comparing apparatus having been improved so as to show differences of 0·001 line. The Commission were not satisfied with making numerous comparisons of these metres and the provisional metre of brass among themselves, but they also compared them repeatedly with the four *Règles de Borda* and a new supplementary measure of above 45 lines, so as to determine not only their relative and absolute length, but also the rates of expansion of the three metals of which they were composed. The rates of expansion definitively adopted by the Commission, from observations made by Borda between 0° and 32° C., were as follows:—

		In a metre.
Coefficient of linear expansion of platinum for 1° C.	= 0·00000856,	or 0·0031 mm.
" brass "	= 0·00001783,	or 0·0092 "
" iron "	= 0·00001156,	or 0.0063 "

The comparisons and corrections of the several metres were continued until no difference amounting to 0·000001 toise, or 0·001 millimetre, could be found at the temperature of melting ice, either in their desired absolute length of 443·296 lines of the Toise of Peru or in relation to each other. They were consequently all determined to be perfectly exact. One of the platinum metres, subsequently known as the *Mètre des Archives*, from its place of deposit, was reserved as the new prototype measure of length; the other was kept at the Observatoire at Paris, as its accessible representative. The twelve iron standard metres were distributed amongst the several countries represented at the Commission.

The primary *Mètre des Archives* is a rectangular platinum bar, bearing no mark or description. Its breadth is 25 mm. (0·984 in.), its height 3·5 mm. (0.138 in.). Its ends are planes perpendicular to its axis of length, and the straight line between them in this axis denotes the true length of the metre at 0° C., or the temperature of melting ice. It thus constitutes what is termed a *Mètre-à-bouts*, or end-standard metre.

The unit of metric weight was defined to be the weight in a vacuum of a cubic decimetre of distilled water at its maximum density, or the temperature of 4° C. Distilled water was selected as the best material in nature for thus determining the unit of weight, from its being obtainable everywhere and at all hours in the greatest purity, its being perfectly homogeneous, and its density being invariable at any given temperature. It was required first accurately to ascertain the weight of this volume of water, and then to construct a metallic standard of equivalent weight. The necessary operations for effecting both these objects were entrusted to M. Lefevre-Gineau in 1795. He had to decide between two modes of proceeding for accurately determining the volume of water to be weighed; one, by measuring the internal capacity of a vessel to contain this volume of water; the other, by measuring externally a solid or hollow body, in order to ascertain the weight of the volume of water displaced by it. He chose this last method, considering that the accurate external measurement of a metallic body was much less difficult than that of the internal capacity of a metallic vessel; and it was determined that the best form of this body was a cylinder of a height equal to the diameter of the base, this form



IG. 10.—Cylinder for determining cubic centimetre.

being capable of being made and measured with the greatest precision.

It was not thought requisite that the cylinder should be of the specified volume of a cubic decimetre, but only of the most convenient size for arriving at the desired result by computation. The cylinder actually used was made of brass, and hollow, being only so much heavier than the same bulk of water as to enable it to sink by its own weight when plunged in water. It was intended to be 2·435 decimetres (about 9½ inches) in diameter and height.

To facilitate the accurate measurement of the cylinder, 12 radial lines or 6 diameters were drawn on its base plane, dividing it into twelve equal parts; and corresponding lines were drawn on its upper plane. The ends of these two series of lines at the circumference were joined by vertical lines on the cylinder, thus dividing it vertically into twelve equal parts. Circular lines were also traced on the two plane surfaces at about 11 mm. from the circumference, and at half and two-thirds of the radius from the centre; and eight horizontal lines were drawn around the cylinder at the following distances from the base:—13, 35, 67, 95, 148·5, 176·5, 208·5, 230·5 millimetres. The height of the cylinder was determined from the ascertained mean distance of the corresponding 37 points of intersection of the lines on the upper and lower surfaces, including the centres. The diameter of the cylinder was determined from the ascertained mean length of the 48 diameters, included between the corresponding points of intersection on its cylindrical portion.

The measurement was effected by means of an apparatus specially constructed for the purpose by Fortin, and it indicated minute differences of length of $\frac{1}{4000}$ line, or $\frac{1}{1700}$ mm.. The standard measures used for determining the absolute length measured were 16 brass measures specially constructed for the purpose, each very nearly equivalent to the height of the cylinder, and 16 other measures, each nearly equivalent to its diameter. The length of each of these two series of measures in relation to each other was ascertained by numerous observations with the new apparatus; and the total length of each set of 16 measures in relation to the new standard unit was obtained by comparing the sum of their length with Borda's *règle* of 2 toises, No. 1, to which they very nearly corresponded in length, by means of the *comparateur* used for the comparison of these large measuring rules.

The final result of the measuring operations was that the mean height of the cylinder was determined to be 2·437672 decimetres, and its mean diameter 2·428368 decimeters, at the temperature of 17°·6 C. According to Borda's determination of the coefficient of the linear expansion of brass, the volume of the cylinder was determined by computation to be nearly 11·28 cubic decimetres, when at the temperature of melting ice.

For ascertaining the weight of water displaced by this cylinder, a series of brass weights was specially constructed, consisting of a unit or provisional kilogram, made as nearly as possible of the estimated weight of a cubic decimetre of water, together with 11 exact copies and smaller weights in decimal subdivision down to the millionth part, all carefully verified and deemed to be accurate within less than half of one-millionth part.

The mean weight of the cylinder in ordinary air was taken, no reduction to a vacuum being deemed requisite, as the weights used were of similar metal to the cylinder, the interior of which communicated with the external air. For this purpose a metallic tube, 1·285 mm. in diameter, was screwed to the top of the cylinder, its end being out of the water when the cylinder was immersed. The top of the cylinder was 43 mm. from the surface of the water during the weighings, and the volume of the tube immersed was therefore 55·77 cubic mm. Taking the volume of the cylinder to be 11·28 cubic decimetres, the volume of the metallic part of the cylinder was computed to be 1·506 cub. decim., and of the hollow part filled with air 9·774 cub. decim. During the weighings the cylinder was surrounded with ice, but the temperature of the water was never below 0°·2 C. and the mean temperature was 0°·3. The final results of the weighings were declared to be as follows:—

	Prov. kilo.
Weight of the cylinder in air, in terms of the unit employed	= 11·4660055
Its mean weight in distilled water, after deducting the weight of air in the cylinder, and of the air displaced by the weights used	= 0·1967668
Hence weight of the volume of distilled water equal to the volume of the cylinder	= 11·2692387

H. W. CHISHOLM

(*To be continued.*)

NOTES

It is announced that the Transatlantic Balloon will leave New York to-day. It will carry four passengers—Prof. Wise and Mr. Donaldson, the aëronauts; an officer of the United States Signal Service, and an agent of the *Daily Graphic*. They hope to reach some point on the English or Continental coast in about sixty hours from their departure from New York. They have with them six very powerful and experienced carrier-pigeons, purchased in Belgium, which, if liberated from the balloon within "pigeon flight" of the coast, are expected to fly directly to their old homes. Each of these has painted on his breast, in indelible ink, the outline of a balloon, and on his wings the words, "Send news attached to the nearest newspaper." Despatches received by these pigeons should be sent to the nearest newspaper for publication. We wish these daring men a safe landing; but while we do this we regard the enterprise as one needlessly hazardous, so far as the settlement of the scientific problem is concerned.

Mr. Campbell, the Chief Secretary of the Inspectorate-General of Customs in China, is now in Europe with a view of obtaining instruments for a complete chain of meteorological stations in that country. It is also proposed to transmit weather information all along the east coast of Asia. This is great news, and we shall return to this important matter, giving full details of the proposals.

Miss Elizabeth Thompson, of New York, has made a donation to the American Association for the Advancement of Science of 1,000 dols., for the purpose of advancing scientific original research; and she intends repeating the donation annually during her life.

M. Stephan has succeeded in finding Faye's Comet The correction of the Jahrbuch Ephemeris is almost *nil*.

Mr. Froude, who is now with the *Devastation*, informs us that it is Mr. W. Barlow, not himself, who is president of Section G at the ensuing meeting of the British Association. Mr. Froude will, indeed, probably not even be able to attend the Bradford meeting at all.

We learn from the *Monthly Microscopical Journal* that Prof. Gegenbauer, of Jena, the well-known comparative anatomist, has been nominated Professor of Anatomy and Director of the Anatomical Institute in the University of Heidelberg.

The arrangement made by Prof. Henry, of the Smithsonian Institution, a few months ago, for the interchange between America and Europe, by Atlantic cable, of important astronomical discoveries and announcements, appears to have borne excellent fruit. One great object of this movement was to enable astronomers in all parts of the world to concentrate attention upon any celestial phenomenon before too great a change of place had occurred, or before the intervention of a long period of moonlight after the first discovery. On the 26th of May last Prof. Henry announced a new planet, discovered by Prof. Peters, to the Observatory of Paris, among other institutions, and on the following night it was looked for by the director of the Observatory of Marseilles, who at once detected it, and subjected it to a careful criticism. The announcement of three planets has thus far been made from the Smithsonian Institution to Europe; the only return communication being that of a telescopic comet, discovered at Vienna on July 5. On being notified of the fact, Prof. Hough, of the Dudley Observatory at Albany, made search for it, and succeeded in finding the object without any difficulty.

Biology is flourishing at the Antipodes. The last mail has brought us "Australian Vertebrata, fossil and recent," by G. Krefft, curator and secretary of the Australian Museum, Sidney; a list of Australian Longicorns, chiefly described and arranged by Francis P. Pascoe, with additional remarks by George Masters, assistant curator of the Australian Museum; Guide to the