THURSDAY, JANUARY 30, 1873

THE INTERNATIONAL METRIC COMMISSION*

IN continuation of the previous remarks upon the proceedings of the Commission, we may now notice some of the more important scientific details of its operations.

The material for constructing the new Standards, for which an alloy of pure platinum with 10 per cent. of iridium has been selected, is obviously a matter of primary importance. Before determining upon this metallic alloy, a series of experiments was made by the French section of the Commission. A material was needed, both for the metre and the kilogramme, that should as far as possible be unalterable in its composition and molecular structure, in its form and dimensions, from the ordinary action of air, water, fire, or other chemical agents, or from mechanical forces to which it might be subject; that would in fact possess physical properties rendering it invariable with time. It should be hard, elastic, and yet not difficult to work. It should at the same time be perfectly homogeneous, so that all the Standards should be as nearly as possible identical in their material. And in order to lessen the unavoidable influences of variations of temperature, it was obvious that a material was most desirable that would experience the least alteration in its dimensions from changes of temperature. Proceeding by an exhaustive process, the Commission decided against employing any of the materials which have been hitherto adopted. Brass and alloys of copper did not satisfy the requirements, and were rejected as liable to be injuriously affected by air and heat, and from being composed of different metals varying in their density and dilatation. Quartz, though satisfactory in many respects, was too fragile and bulky; besides which there existed no prospect of obtaining it of sufficiently large dimensions and of the requisite purity. In addition to the objections attaching to quartz, glass was inadmissible by reason of the disturbing influences of moist air on its surface, and from its molecular condition as a tempered and crystallised body rendering it liable to changes from variation of temperature which might affect the constancy of its density, expansion, and even length; for it was thought that a glass metre, like a steel metre, would thus become shorter in course of time. Even platinum, which was the best pure metal for the purpose, has the disadvantage of being too soft and too weak for a measuring bar. Combined, however, with a proper proportion of iridium, platinum satisfied all the conditions required either for a Standard metre or kilogramme. These two metals have the same system of regular crystallisation, the same density and rate of expansion, and when alloyed in proper proportions, they produce a perfectly homogeneous material. They are the two metals which of all others dilate the least by heat, and the proposed alloy of 10 per cent. of iridium has been proved to have as nearly as possible the same density and the same rate of expansion as the existing Metric Standards, the *Mètre* and the *Kilogramme des Archives*. This fact alone is important as greatly facilitating the identity of the length and weight of the new Standards with those of the original prototypes of the Metric System. Platinum-iridium has also been proved to be extremely hard and rigid, and to possess the greatest elasticity, as well as cohesion or resistance to fracture. At the same time, it is easily cut with a diamond, and it has been shown that lines $\frac{3}{1000}$ of a millimetre apart (or 0·00035 inch), so cut upon it, with the aid of a microscope, are perfectly regular, even when magnified from 300 to 600 times.

* Continued from p. 197.

The experiments of M. Regnault have shown that platinum-iridium resists the penetration of absorbent gases, and further experiments made by the Commission prove that the influence of such gases can in no way cause any change, either in its volume or its weight. A more severe test had already been applied to platinum by M. Stas at Brussels. He subjected a platinum kilogramme successively to the action of alcohol, cold water, boiling water, drying in a vacuum, and heating in a red heat of from 250° to 300° C., whilst guarded from flame; and he ascertained by comparisons in moist air, at a temperature of 15° C., with a platinum kilogramme not subjected to any of these conditions, that no change whatever had occurred in the weight of the kilogramme so treated. It was only requisite to allow a certain number of days, at most a fortnight, to elapse for the platinum to recover itself.

Another important question was that of the form to be given to the new metre. The present *Mètre des Archives* is a bar of platinum with a rectangular section, 25 millimetres wide, and 4 millimetres deep (or about 1 inch by $\frac{1}{6}$ inch). It had been determined that the new metre, which was to be a standard *à traits*, or line-standard, should have its defining lines marked at mid-depth of the bar, on the same principle as our English standard of length, in order that the actual length of the measure should be as little as possible affected by any difference of temperature, and consequently of dilatation, between the upper and lower surfaces of the bar. But the Commission objected to the English mode of sinking cylindrical holes to the mid-depth of the bar, and tracing the defining lines on the plane surface of the bottom of these holes, as being not only inconvenient on many accounts, but also as interfering with the uniformity of structure of the bar during its whole length. The form of the new *mètre à traits* mentioned in the resolutions as having been proposed by M. Tresca, one of the secretaries of the commission, who had given much study to the question, and laid an elaborate note upon the subject before the Commission, is of a very ingenious and entirely novel character. Its transverse section may be described as taken from the form of the letter X, if divided down the middle into two halves, and then joined by a band equal in thickness to the other parts (3 millimetres). By lowering the upper surface of this band to the mid-depth of the bar, it gives a continuous plane, upon which not only the two defining lines of the metre can be cut, but also any intermediate lines that may be required as subdivisions of the metre. By a further slight reduction in the thickness of the lower half of the sectional figure, the defining lines will lie not only in the length of the neutral axis of the bar, but also in that of its centre of gravity. The dimensions of the bar itself when first constructed are to be 102 centimetres in length, and 2 centimetres square in section, and the bar is afterwards to be planed to the form decided upon. Its weight will thus be reduced to about 3¼ kilogrammes, and the defining lines of the metre will be cut at the distance of 1 centimetre from each end of the bar.

There appear to be many advantages in this new form of measuring bar, of a geometrical, mechanical, thermal, and economical character. Much importance is attached to the absolute uniformity of the bar throughout its whole length, as equalising its resistance and molecular action, and also to the adoption of a geometrical form as symmetrical as possible. The absence of any acute angle was also dwelt upon as facilitating the mechanical displacement of the surplus metal; and it has since been practically ascertained that the planing can be executed with the utmost regularity and precision. It will also prove an excellent test of the soundness of the metal throughout the whole length of the bar. The great rigidity of this form of bar, combined with the advantage of the high elasticity of the platinum-iridium, was fully shown; as compared with the rigidity of the *Mètre des Archives*, it will be as 25·9 to 1, although its sectional area is only half as much more. The new form will also be highly favourable for equalising the temperature throughout its whole length and thickness, and for taking the temperature of the surrounding medium; and it will afford a most convenient lodgement for mercurial thermometer tubes, thus enabling the actual temperature of the measuring axis of the bar to be readily and accurately determined. This measuring axis will be in one open and unbroken line, and quite unaffected in its dilatation by any contact with the support of the bar. Lastly, in an economical point of view, the form proposed will give the greatest possible strength with the least quantity of the costly material used.

This form for the *mètre à traits* can be employed with merely a slight modification for any *mètres à bouts*, or end-standards, that may be required. The form of the bars for the *mètres à bouts* will have a similar sectional figure, but symmetrical, the measure being defined by the spherical end of two small cylinders, 3 millimetres in diameter, and projecting 1 millimetre from the middle of the ends of the bar, the radius of curvature being 1 metre.

One other point may be noticed as to the mode of determining the temperature and dilatation of the standards. The temperature at which the new metre will have its true length has been decided to be the same as that of the *Mètre des Archives*, that is to say, 0° C. All the necessary arrangements have been already made for making comparisons at this temperature by constructing a cold chamber expressly for the purpose, and surrounding it with non-conducting materials. By a blast of cold air driven by a steam-engine in an adjoining room over a surface of ether and through pipes into the cold chamber, the temperature in it may be reduced in a few hours to the freezing point, and maintained constant there. From this adjoining room also the requisite light is conveyed into the cold chamber, and is thrown by reflection on the bars and apparatus. There is an inner part of the chamber in which the standard metres and the comparing apparatus are placed, whilst the observer is enabled to make the adjustments and the comparisons through the microscopes from an outer part, and thus the heat of his body is prevented from exerting any disturbing influence on the bars and apparatus.

Many comparisons of the metre will, however, be made at other temperatures, and in all such cases, as well as for ascertaining the rate of expansion of the bars, the accurate determination of the temperature by thermometers will be requisite. The question of the amount of dependence to be placed on the indication of the temperature by mercurial thermometers, which has recently been a good deal agitated in this country, was considered by the Commission to be one of great importance. They found that in all mercurial thermometers, the dilatation of the glass envelope, which, so far as it is known, is only about one-seventh that of the quicksilver, renders the reading of the best calibrated thermometers liable to errors amounting to some tenths of a centesimal degree. The best authorities are also of opinion that implicit dependence cannot be placed on the constancy of mercurial thermometers, so far as they indicate the temperature, nor on the constancy of the dilatation of the glass envelope. It was thought, therefore, that for ascertaining the temperature with a degree of precision exceeding 0°·1 C., recourse must be had to an air thermometer.

On the other hand, the air thermometer is an instrument complicated in construction and difficult to use. It requires the greatest precautions and practised skill in its manipulation; and the necessity of having recourse to an air thermometer on every occasion of making comparisons with the primary standards would create very serious embarrassments. On these grounds it was decided that every one of the new metres should be accompanied by two detached mercurial thermometers, carefully compared with an air thermometer, and which should be re-verified with it from time to time.

It was stated to the Commission by M. H. Saint-Claire Deville, as the result of twenty years' use of an air thermometer, that no instrument could be more precise and convenient in reading, more easy and expeditious in use. He estimated that by employing an air thermometer according to a method suggested by him, the mean temperature of a standard metre under comparison could be determined with precision to the $\frac{1}{240}$th of a degree of the centigrade scale.

On the subject of dilatation, we can only briefly allude to M. Fizeau's admirable method of accurately determining the rate of expansion of solid bodies by heat, by employing the length of a wave of monochromatic sodium light (a constant = 0·005888 millimetre, or 0·00002318 inch), as his standard of measure. By means of an ingenious apparatus constructed by M. Soleil, the yellow ray is made to fall vertically through a piece of plate glass on a horizontal plane of the solid body, and is reflected in the under-surface of the glass. By counting the number of Newton's rings passing a fixed point upon the glass, when they are set in motion from the expansion of the surface of the solid body by observed degrees of heat, its dilatation can be computed with the greatest precision. This method has been described in the proceedings of the Royal Society on November 30, 1866, when the Rumford gold medal was awarded to M. Fizeau for it. The Commission also hope to obtain a standard of dilatation by marking a measure of length of one or two decimetres upon the plane surface of a piece of Beryl in its axis of non-dilatation. M. Fizeau has shown that Beryl varies in its dimensions from heat less than almost any other body, and that it possesses this peculiarity, that whilst it expands by heat in the direction of its axis of crystallisation, it contracts by heat in the direction perpendicular to this axis; consequently in the line of the proper intermediate angle there is no dilatation or contraction whatever from heat. Endeavours will therefore be made thus to obtain an invariable standard measure of length, by comparison with which the rate of dilatation of measures variable with heat may be determined.

There are other subjects of the investigations of the committee which might be noticed, but we have probably stated enough to enable some idea to be formed of the magnitude of the work undertaken by the International Metric Commission, and of the value and importance of the anticipated results of their labours; as well as the advantages expected to be obtained from the proposed establishment of the permanent International Metric Institution. H. W. CHISHOLM

DE MORGAN'S BUDGET OF PARADOXES

A Budget of Paradoxes. By A. De Morgan. (Longmans, 1872.)

THIS work is absolutely unique. Nothing in the slightest degree approaching it in its wonderful combinations has ever, to our knowledge, been produced. True and false science, theological, logical, metaphysical, physical, mathematical, &c., are interwoven in its pages in the most fantastic manner: and the author himself mingles with his puppets, showing off their peculiarities, posing them, helping them when diffident, restraining them when noisy, and even occasionally presenting himself as one of their number. All is done in the most perfect good-humour, so that the only incongruities we are sensible of are the sometimes savage remarks which several of his pet bears make about their dancing-master.

De Morgan was a man of extraordinary information. We use the word advisedly as including all that is meant by the several terms knowledge, science, erudition, &c. Everywhere he was thoroughly at home. An old edition and its value-giving peculiarities or defects, a complex mathematical formula with its proof and its congeners, a debated point in theology or logic, a quotation from some almost-unheard-of author, all came naturally to him, and from him. With a lively and ready wit, a singularly happy style, and admirable temper, he was exactly fitted to write a work like this. And every page of it shows that he thoroughly enjoyed his task. Witness, for instance, the following extract:—

"I will not, from henceforward, talk to any squarer of the circle, trisector of the angle, duplicator of the cube, constructor of perpetual motion, subverter of gravitation, stagnator of the earth, builder of the universe, &c. I will receive any writings or books which require no answer, and read them when I please: I will certainly preserve them—this list may be enlarged at some future time. There are three subjects which I have hardly anything upon: astrology, mechanism, and the infallible way of winning at play. I have never cared to preserve astrology. The mechanists make models, and not books. The infallible winners—though I have seen a few—think their secret too valuable, and prefer *mutare quadrata rotundis*—to turn dice into coin—at the gaming-house: verily they have their reward."

He was not, let it be at once said, a great original mathematician—not, that is, of the order of men like Boole or Rowan Hamilton—but extraordinarily great mathematicians like these are very rare, and there were not in Britain a dozen who were his superiors. We are told in the Preface to this work that it was his intention to have composed a companion volume on "the contradictions and inconsistencies of orthodox learning." What a loss we have here sustained—how narrow an escape several of our most popularly idolised men of science, &c., have made—must be known to many, perhaps even dimly suspected (at least we hope so) by those who would assuredly have been the earliest and most prominent sufferers.

A great part of the volume consists of reprints from a series of almost weekly papers in the *Athenæum*; but much new matter has been added, and several modifications and corrections have been made. The task of editing has been undertaken by the author's widow, and appears to have been exceedingly well done throughout. The volume is not one which can be read through at a sitting—nor even at three or four: the multiplicity of subjects renders it bewildering if more than a dozen or two of pages be read at a time—but we do not envy the man who cannot, at a spare moment, find both pleasure and profit in the perusal of a moderate portion of it, taken *ad aperturam.*

De Morgan was a very dangerous antagonist. Ever ready, almost always thoroughly well informed, gifted with admirable powers of sarcasm which varied their method according to the temperament of his adversary, he was ready for all comers, gaily tilted against many so-called celebrities; and—upset them. It is unfortunate that the issue of his grand contest with Sir William Hamilton (the great Scottish Oxford Philosopher) is but in part indicated in this volume—it is softened down, in fact, till one can hardly recognise the features of the extraordinary *Athenæum* correspondence of 1847. There the ungovernable rage of the philosopher contrasts most strongly with the calm sarcasm of the mathematician, who was at every point his master, and who "played" him with the dexterity and the tenderness of old Isaak himself! But it is characteristic of De Morgan that, though he was grievously insulted throughout the greater part of this discussion, no trace of annoyance seems to have remained with him after the death of his antagonist; for none would gather from the "Budget" more than the faintest inkling of the amount of provocation he received.

Yet De Morgan had his weak points, and in an unguarded moment he made a first, and last, attack—one of the few assaults in which he was unsuccessful—on Faraday. At least he gets the credit of having reviewed a lecture of Faraday's in the *Athenæum* of 1857, and of having for once wholly missed the main point at issue.

To return to the "Budget." The tenderness displayed for trisectors, duplicators of the cube, circle squarers, perpetual motionists, *et hoc genus omne*—from J. Reddie through J. Symons, to J. Smith—is most touching. The real human interest evidently taken in the careers of those hopelessly ignorant writers, does credit to De Morgan's heart. He does not hang up his Paradoxer on high as a warning, nor does he dissect him for purposes of psychological study; he carefully spreads him out, under sufficient but not extravagant pressure, on the white page of his herbarium, and fondly preserves him as a specimen