THE DECIMAL METRIC SYSTEM

FOUNDATION
INTERNATIONAL ORGANISATION
FUTURE DEVELOPMENT

BY

ALFRED PEROT
PROFESSOR IN THE POLYTECHNIC SCHOOL
MEMBER OF THE NATIONAL BUREAU OF WEIGHTS AND MEASURES

PARIS
TYPOGRAPHIE PLON-NOURRIT ET Cie
8, RUE GARANCIÈRE — 6e

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Gift of French Govt.

ON THE DECIMAL METRIC SYSTEM

SOME HISTORICAL DATA

The first notion of the Metric System can be traced to a far remote past.

Without recalling the various attempts made in former times with the view of attaining the unification of weights and measures, it would be unfair not to mention Curate Mouton, who in 1670 proposed a system of measures the basis of which was the length of 1 minute of the arc of the great circle of the earth, and whose multiples and submultiples were formed according the decimal law. The principal underlying this system gives to it an analogy with ours.

After him, some astronomers, Picard, Huygens, La Condamine, proposed to take as a basis the length of the pendulum beating the second at a given place. It was in 1790 that Talleyrand introduced before the National Assembly, which adopted it, a bill tending to the unification of all measures, starting from the length of the pendulum beating the second at the latitude of 45°; a commission of the Academy of sciences, to which the project was submitted, adopted the decimal division, and proposed to assume as the basis of measures the forty-millionth part of the terrestrial meridian; on march 30, 1791, the principles of the decimal Metric System were adopted by the National Assembly.

From that time, and notwithstanding all the events which stirred France and Europe, the organisation of the new system was carried on almost without an interruption, till the law which established it definitively was promulgated.

France was then at a moment of her history when projects became realities with extraordinary vigour and speed. Thanks to their resolute spirit, which uprooted customs and habits, the rulers of the time made the decimal Metric System legal and compulsory within one year by the decree of August 1, 1793; this decree, as well as the organic law of the *18th germinal an III* (april 7, 1795) gave a provisional value of the Meter as a basis to the system, pending the completion by the temporary commission of weights and measures of the measuring of the part of the meridian comprised betwen Dunkirk and Barcelona. What Parlement would at the present time dare to act so boldly and with such dauntless energy!

The law of *l'an III* introduced the Gram as the unit of weight, in reality of mass, the word weight being then synonymous with quantity of matter.

It was the law of the 19th *frimaire an VIII* (December 10, 1799) which fixed the definitive value of the Meter (3 feet 11, 296 lines) and consequently also the mass-unit. The corresponding platinum standards had been deposited on the 4th *messidor an VII* (June 22, 1799) in the French Archives. Their new copies, executed by the international Meter Commission, were sanctioned in 1889 by the first *general Conference of weights and measures*, and constitute the international Prototypes.

Now, while it took only nine years to obtain the measure of the arc of the meridian and the completion of the meter in the Archives and that of the standard kilogram, nineteen years were spent (1870-1889) in the making of the present copies. One cannot but be surprised at the speed with which the initial work was carried on, especially when one thinks of the material difficulties which the workers had to overcome. Indeed, to the first Academy commission succeeded a temporary commission for weights and measures, which was afterwards weeded out and reorganised; Delambre and Méchain, who measured the arc of the meridian, had to interrupt their operations for over one year, and Delambre himself, against whom the revolutionary Club of Melun lodged an information, received his dismissal from the « Comité de Salut Public ». Fortunately, owing to the events of those troublous times, he was forgotten, and succeeded in carrying out his work.

The Meter according to Clarke (1880) is too long by less than 0,2 millimeter; according to Bessel (1841) by less than 0,1 millimeter.

As regards the Kilogram, worked out by Lefèvre-Gineau and Fabbroni, it is only recently that an exact appreciation of the mistake made by these scientists was arrived at : it amounts but to $\frac{27}{1\,000\,000}$; the Kilogram being too heavy.

We see then with what perfection the standards were worked out, and we cannot too much admire the ability of the constructors of the Kilogram, whose slight miscalculation was set straight by means of the recent optical methods for measuring lengths, inaugurated by Fizeau and Michelson of Chicago.

INTERNATIONAL ORGANISATION

From the start, the founders of the Metric System never lost sight of the advantages that would accrue from its spreading over the different countries of the world. Fully convinced as they were that a system of measures common to all nations would be indiscutably the best, the most favourable to all commercial transactions, our fathers of 1790 made up their minds to found the system on the basis of a quantity which is the common property of all the nations of the world, and on the density of a body of universal diffusion. One might almost say that they foresaw the development of the world trade and of the ever more imperious demand of international industry.

From the very start in 1790, the National Assembly determined upon inviting England to contribute to the foundation of the new system, and in 1798 ten foreign scientists were asked to assist in the work of authentically and solemnly fixing the principal units of the new system. Among these was the Dutchman Van Swinden, to whom we owe the report on the length of the Meter, and the Swiss Trallès, who was entrusted with the report on the Kilogram. It may be said in consequence that the internationalisation of the Metric System dates from the first days of its creation.

It took long years, in spite of Trallès and Van Swinden's endeavours, before the progress of the Metric System was in train. The universal exhibitions greatly contributed towards its diffusion. In 1867, at the Paris exhibition, an « international committee of weights and measures and moneys » was formed. In the international Geodesic Association, in 1867, a motion was carried in favour of the unification of weights and measures and of the adoption of the Metric System.

At last, on the 8th August 1870, the international meter Commission met for the first time. From that day there was no longer any doubt about the internationalisation of the system. It was resolved that copies of the meter in the Archives should be made by construction of *traced meters* and also copies of the standard kilogram.

THE INTERNATIONAL COMMISSION

Assembled in 1872. Thirty states, eleven of which belong to America, were represented. The United States delegates were J. Henry and J.-E. Hilgard.

The commission came to a decision to start from the Meter and to deduce the Kilogram from the standard in the Archives. A standing committee of twelwe members was formed.

The French section, which since 1869 to 1872 had been paving the way for the committee, joined in the work of the international commission in close collaboration with the standing committee.

In 1875, the diplomatic Conference of the meter sat for the first time, vhere the plenipotentiaries and the delegates of twenty states met. The Convention which was the result of the work of this conference gave birth to the International Bureau of weights and measures, established at the Pavillon de Breteuil at Sèvres near Paris.

A few delegates of the Bureau and of the French section, MM. Broch, Fœrster and Stas, Dumas, H. Tresca and Cornu, worked out in iridioplatinum the definitive standard of the Meter and of the Kilogram, and gave their thoughts to the important question of the measures of temperature.

The first general Conference met in 1889, and ratified the international prototypes, which were deposited at Sèvres, and the national standards of the different states.

Since that time, there has been no slackening in the work of the International Bureau; it is, at the present moment, revising the national standards; and its admirable work has been of powerful assistance in the extension of the decimal Metric System.

The general Conference meets every six years at Paris and Sèvres. Every two years, the international committee holds its sessions at Sèvres also, and the International Bureau is its executive department.

At present, the decimal Metric System is compulsory in thirty-two States which are : Argentina, Austria, Belgium, Brazil, Bulgaria, Chili, Columbia, Costa-Rica, Denmark, France and her colonies, Finland, Germany, Guatemala, Holland and her colonies, Hungarya, Honduras, Italy, Luxemburg, Mexico, Montenegro, Norway, Nicaragua, Perou, Portugal and her colonies, Roumania, Salvador, Serbia, Siam, Sweden, Swizerland and Uruguay.

It is optional in twelwe States : Bolivia, Canada, China, Egypt, the United states of America, Great Britain and Ireland, Greece, Japan, Paraguay, Russia, Venezuela. It has been legal in great Britain and Ireland since 1908.

REASONS OF THE DEVELOPMENT OF THE METRIC SYSTEM

The reasons to which the favourable reception of the Metric System is due are three, viz : Firstly. The divisions are in accordance with numeration. It results from this that the passage from a unit to one of its multiples or submultiples is effected by means of the mere displacement of the comma of the number which expresses the measured quantity.

To convert meters into kilometers, the number is to be divided by 1 000 : 3 245 meters = 3,245 kilometers.

To convert square meters into square decimeters, the number is to be multiplied by 100 :

$$3^{m^2} = 300^{dm^2}.$$

To convert cubic centimeters into cubic decimeters, the number is to be divided by 1 000 :

$$2\,196^{cm^3} = 2{,}196^{dm^3}.$$

Secondly. The derived units, surface and volume, are directly deduced from the length-unit.

The square raised on a length-unit is a surface-unit : thus the square of one centimeter side is the cm^2.

The cube raised on a length-unit is a volume-unit : thus the cub of one dcm edge is the dm^3.

It results from this that the surface and volume measures are formed by directly introducing into the calculations the geometric lengths without any coefficients special to the system of measure. The volume in cm^3 of a rectangular parallelipiped will be obtained by multiplynig the numbers expressing in cm the lengths of its three edges.

Thirdly. The bases of the system derive from nature and are independent of any particular country. The forty-millionth part of the terrestrial meridian is the same for all men, just as the density of water is the same.

True it is that these définitions are nowadays but of philosophic value; it is none the less certain that the standards in the Archives were made to carry them out, and that the execution is sufficiently perfect to permit us to look upon the Meter and the Kilogram as accurate images of the primary definitions. The decimal Metric System indeed is true to the motto inscribed on the medal voted by the Assemblée constituante :

« For all times; For all nations ».

Further development in France

At the time of the creation of the Metric System, industry was not able to produce and employ the powers which are now at its disposal and which it has to measure : trade did not carry on transactions depending on energy, light, etc... Geometric measures and mass measures were the only ones which the originators of the system had to bear in mind. Now this is no longer the case; mechanical, electrical units are to be used in contracts and it is necessary that these units should have a legal character equally with the length and mass units.

The introduction into the fundamental units of the time-unit, and thus of those units which derive from it, allows the constitution of a complete system on the plan of the C. G. S. (centimeter, gram, second) system and provides for all industrial and commercial necessities.

A project has been devised in France; the law which fixes the fundamental units was voted by the Chamber of Deputés and is submitted to the examination of the Senate.

This project divides the units into principal units fixed by a law, and derived units fixed by an administrative rule.

The principal units are the units of : length (meter); mass (kilogram); time (second); electrical resistance (ohm); intensity of current (ampère); thermometry (centesimal degree); and luminous intensity (decimal candle).

The secondary units comprise the geometric units (surface, volume, and angle), the units of mechanical density (force, energy, power, pressure), the electric-units (electromotive force and quantity of electricity), calorific units (quantity of caloric), optic units (luminous flux, lighting, power of optical glasses).

The mechanic units are deduced from the coherent system meter-ton-second (M. T. S.), which gives as power-unit the kilowatt and is thus connected with the electrician's working system, whose units are besides incorporated in the project.

The whole scope of the project is indicated in the following very summary table.

UNITS.

Geometric.	length	*meter*.
	surface	square meter, are.
	volume	cubic meter, liter, stere,
	angle	straight angle.
Mass.	mass	*kilogram*, ton.
	density	dosimetric degree. centesimal alcoholic degree.
Time.	time	*second*.
Mechanic.	force	sthene.
	energy	kilojoul.
	power	kilowatt.
	pressure	pieze.
Electric.	resistance	*ohm*.
	intensity	*ampere*.
	force	volt.
	quantity	coulomb.
Calorific.	thermometry	*centesimal degree*.
	heat	thermy, calory.
Optic.	luminous intensity	*decimal candle*.
	luminous flux	lumen.
	lighting	lux.
	power of optical glasses.	dioptry.

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