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## **The decimal metric system: Facing scientists and population in France**

### **Abstract**

Following the changes brought by the 1789 Révolution, a new system, for weights and measures, was created. New measurements of a meridian arc were made and final decision taken in 1799. Despite the interest showed by the scientists, the population was against, as usual in France when something has to modify the habitudes. Forty years later an hard decision was taken, in 1837, for application from 1st January 1840.

### **Key-words:**

Meridian, meter, Mètre, Metric system.

### **(1) Prologue**

It's not surprising to encounter difficulties every times something new is introduced in current life. The Metric System would not escape similar occurrences, despite the fact, all over Europe, that unification of weights and measures was requested, and despite the attempt which, first, occurred with Charlemagne around 789, ten centuries before the French Revolution in 1789.

In France, after several proposals which began mostly at the time the Royal Observatory was built from 1667, the French Revolution (1789) brought new ideas, more easy to introduce, at least apparently. Decisions were taken during successive years from 1790 with the leadership of the *Académie Royale des Sciences*, asked by the Government to study the unification. Subject for discussion was the necessity or not to remeasure the meridian to get the value of the new unit, considering that it was a vain affair to find an exact length for it, issued from some part of the nature. And why not take, as a reference, the French *toise* as suggested by Lalande in 1790: *La toise de Paris est si célèbre dans tout l'univers que je ne pense pas qu'il faille la changer pour y substituer le pendule à secondes...* The same would be true for any other length.

Later, Lalande would write (1799 June 16) to Flaugergues (1755–1830), an amateur astronomer from the south of France, that he was opposed to any sort of campaign to remeasure the meridian: *Je m'y suis opposé en 1792; mais l'amour-propre de Borda, qui vouloit faire valoir son cercle l'emporta à la Cadémie* (instead of *l'Académie*, an expression employed by a part of the population at the time of the Révolution), *en disant que pour faire passer notre nouvelle mesure, il falloit une grande et importante opération*. Indeed the Borda (1733–1799) circle, thus in question, had shown, on several occasions, that it was quicker in use, smaller than other instruments and, at that time the most precise.

Contacts with Great Britain and Sir Riggs Miller, member of the Parliament, was favourable to a new unit based on the length of the second-pendulum, despite the fact that the latitude of London, rather than the 45 degrees proposed by France, would have been better considered. All was stopped when he left the Parliament in 1790. Contact with the US, at the time of Jefferson, were also taken. For the same subject they were considering the mean latitude of the country, 38 degrees. Such differences had shown that the length of the second-pendulum was not as universal as it was previously thought and this solution was abandoned. The length of part of the equator was abandoned for a similar reason. Lalande, in 1790, had made the suggestion to make a choice not associated to an experimental and supposed «natural» reference, which could be different from place to place and with time.

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Another point considered was the possibility for every one to remeasure any part of any meridian arc all over the world, better responding to Condorcet's wishes: *A tous les temps – A tous les peuples*. A half *toise*, as suggested by Lalande would have not been so easy to fulfil this assertion.

It was decided (1790 October 27) that the new system would be decimal and every weight and measure deduced from a fundamental unit.

## (2) The MÈTRE

It had appeared that a length of about a half *toise* was convenient for the current employments. It was also seen that sub-multiples or multiples, by power of 10, would be appropriate for shorter lengths, for larger ones, for surfaces, for volumes ... On the other hand a weight of about one pound was appropriate and, fortunately, two pounds had about the weight of a cube, full of water, having sides equal to one tenth of a meter, it will become a *kilogramme*. A new commission, created by the *Académie*, decided (1791 March 17) to name *mètre* the length which will represent the fundamental base of the new system for weights and measures and that it will be equal to  $1/10$  power 7 of one fourth of a terrestrial meridian.

Delambre (1749–1822) and Méchain (1744–1804) were asked to remeasure the Paris Meridian to determine the length of the new unit: the *MÈTRE*. By reason of the events of the time the operation began in 1792; it was in some places difficult. Time going on, it was decided, in 1795, to choose a provisional length for the *mètre*. The choice was made of the length issued from the measurement made by Lacaille (1713–1762) and Cassini the third (1714–1784) around 1740. Its length was 3 *pieds* 11.44 *lignes*.<sup>1</sup> The name *MÈTRE*, according to Delambre, was issued from a proposal presented by Borda (1733–1799).

By the end of the operation, that time from a sea level (Dunkirk) to another sea level as a reference, in Barcelona,<sup>2</sup> the final decision was taken in 1799 by an international committee, at that time european. Its president was Van Swinden (1746–1823), a Batave, and it included representatives from Spain, Danemark, Sardinia and the new republics, according the division of Western Europe, nowadays corresponding to Low Countries, Switzerland, Italia .... Among several possible values, the committee made the choice of 3 *pieds* 11.296 *lignes*, a difference of about one third of a millimètre.

The new references, the «*mètre*» for lengths, the «*kilogramme*» for weights, were presented to the French assemblies on the day 4 messidor year VII, France leaving under the republican calendar of decimal character. It is said that Laplace (1749–1827) had to pronounce the discourse on that day: June 22 in 1799. The corresponding law was passed on 19 frimaire year VIII (December 10, 1799). To get the different powers, prefixes are chosen for the *mètre* such as *décamètre* for ten *mètres* or milli for *millimètres*, one thousandth of a *mètre* .... To take note: the fact that the reference for weights is named *kilogramme*, with a prefix which is not the case for the *MÈTRE*.

On April 7, 1795, the nomenclature was fixed. Besides the *MÈTRE*, the *ARE* is a square having its side of 10 meters, the *STÈRE* is a cube meter, *LITRE*, for liquids is a cube which sides are one tenth of *mètre*, and the *gramme* with a hundredth of it. The prefixes for multiples and sub-multiples are chosen among greek or latin vocabulary. Nowadays from power -24 to power +24 different other languages are employed.

The coins followed the system with weights such as 5 *grammes* for 1 *franc*, and diameter in *millimètres*.

## (3) Two decades of difficulties and more

As soon as the definitive decision was taken the populations was against, apparently mostly because of the new names decided by the *savants*, and with prefixes chosen, not among French words, but from «strange» ones. Another difficulty was due to the general use of the same name for different fields in current life such as grains and dry matters, liquids, firewood ... There were also different names for sub-multiples. Some french examples for old names are given below.

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<sup>1</sup> The *pied* is equal to 32.5cm and the foot 30.5cm. One *toise* is 6 *pieds*, one *pied* is 12 *pouces* and one *pouce* 12 *lignes*.

<sup>2</sup> From the year 2000, a profile of the measured arc lies in a park nowadays more or less abandoned.

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Length		<i>Toise</i>	<i>Pied</i>	<i>Pouce</i>	<i>Ligne</i>	<i>Point</i>
		1 =	6	72	864	10 368
			1/6 =	1/12 =	1/12 =	1/12
Weight	<i>Livre</i>	<i>Marc</i>	<i>Quarteron</i>	<i>Once</i>	<i>Gros</i>	<i>Grain</i>
	1 =	2 =	4 =	16 =	128 =	9216
		1/2	1/2	1/16	1/8	1/8

Volume according to the matters

Grains	<i>Muid</i>	<i>Setier</i>	<i>Boisseau</i>		
	1 =	12 =	144		
Liquides	<i>Muid</i>	<i>Quartaut</i>	<i>Pinte</i>	<i>Pot</i>	
(Paris)	1 =	72 =	288 =	576	

Bois      *1 corde = 3 stères (1 stère similar to 1 m<sup>3</sup>)*

*1 charretée = 2 stères*

*1 voie = 1 quantité par porteur / voyage*

Being used with all these names, according to the in cause matters to measure, people were not so inclined to change their habits even if a *toise* was about two *mètres*, one *pied* close to one third of a *mètre* or thirty *centimètres*, a *pouce* between two to three *centimètres*, a *ligne* as a few *millimètres*. From these examples it is seen that one of any of these new units was appropriate to the different measurements. But the names were new, even if more simple in use with the unique decimal character.

Such difficulties could be at the origin of the decision taken as early as November 4 of the year 1800, less than one year after December 10, 1799. On one side the decimal metric system would be in use all over the country from 1801 September 23, being *vendémiaire* 1 of the republican year X. But on the other side to facilitate the use, names for weights and measures could be *livre* (pound) for *kilogramme*, *doigt* (finger) for *centimètre*, *pinte* (pint) for *litre* and so on ... Confusions and frauds, in reason of the differences with real lengths or weights were frequent.

The situation came to be more complicated after the decision taken by Napoleon's time, 1812 February 12, when it was decided to abandon the decimal division of the units, followed by another decision taken on the following March 28. According to a study made by Louis Marquet, a French specialist of metrology now dead, the harvest of wheat, in 1811, was very bad; on the other hand the napoleonic wars were still on. The price of wheat became very high and the population was taken the new units as responsible of its cost. The *préfets*, in charge of the application of the new units, in their departments, informed the Government about a return to the ancient units which could bring an end to the difficulties.

The new decisions were complicated. For the current employments, by the people, in the every day life and shops, the old units would come back a new time. Doing so, one *toise*, equivalent to two *mètres*, was divided into six *pieds*, each one being equivalent to a third of one *mètre*,... As another

exemple is the *livre* which was 489 *grammes* in 1789, and became equivalent to a *kilogramme* in 1800 and half a *kilogramme* in 1812. At the same time, the legal measures, still those in 1799, had to be employed for public works and in commercial transactions, and the decimal system had to be taught at the various levels. Some old weights of the time are bearing the two indications: 250 *grammes* for a half *livre*, and 4 *onces*, 25 *grammes* instead of a little bit more than 30 *grammes*.

At the time Napoleon was in the Elbe Island, Louis XVIII was asked, in July 1814, to take a decision favouring the decimal metric system. From 1816, February 21 a new decision was taken; it confirms the use in shops of old units such *aune* (118 instead of 120 *centimètres*), ... All these decisions would be abrogated in 1825.

Meanwhile, the most educated persons had understood the qualities of the cartesian character of the metric system and its most important aspect, its decimal feature together with the uniformization. As an example, the astronomers.

#### (4) The French astronomers and the metric system

Scientific reactions were different according to the persons, even if all of them would be favouring a better system as the previous ones and, certainly, uniformized to a certain level to avoid difficulties in the commercial exchanges. This was particularly true between countries, but even, in one country differences were occurring between domains.

Among the scientists Borda, at the origin of the repeating circle made by Lenoir (1744–1832) as soon as the mid-eighties of the 18th century, was a fervent adept of the decimal character of the new system. This was most probably the reason for which, among the four Borda/Lenoir circles employed by Delambre et Méchain, two were in usual degrees, two in grades (100 for the right angle instead of 90) nowadays called gons.

The French astronomers had, among their national publications and from 1679, an almanach under the form of *Connaissance des tems*. At the creation of the French *Bureau des longitudes*, in 1795, the publication went from *Académie des sciences* to this Board of longitudes. The metric system was mentioned, for the first time, in its issue for the year 1795 with the form *Notice sur le système des Mesures déduites de la grandeur de la Terre, pour servir uniformément dans toute la République Française*.

The notebooks of the Paris Observatory do not include, at that time, metric data for the barometers; those in use had not been changed. The first mention in metric units, is found on January 22, 1804: the numerical value is also given in *pouces* and *lignes*, up to November 1808. At the date November 24, a new barometer, divided in *millimètres*, is installed. The transformation into *pouces* is still there up to 1810. Similarly the rain is given in *millimètres* from December 1803.

From these examples it is seen that the astronomers introduced the metric system as soon as the appropriate instruments could be provided. It seems that it is true to consider that it was the same in other fields of science. While the mathematicians, such as Poisson (1789–1840), who employed the decimal metric system from 1803, the astronomers and others had to wait new instruments.

For decades, instruments of decimal character began to be built mostly for scientists and also for engineers working in the field of road works. Laplace also played a rôle to push the authorities, at various epochs, to take some valuable decisions. On the other hand teaching, in school, had to concern the metric decimal system as the only one, at least in the public schools which, in France, means not religious but state schools.

By the mid-thirties of the 19th century, two generations of children had been taught in the decimal metric system so that it could be time to take a final decision.

#### (5) Years 1837–1840

Better decisions will come when Thiers, then in power under King Louis-Philippe, recalled the official decisions to the *préfets* and prepared a project for a new law to be issued in 1837.

The story began on the 4th of May 1836 when Louis Puissant (1769–1843) an *ingénieur géographe* at the *Dépôt de la guerre*, the service in charge, at that time, of the maps for France, informs the *Académie des sciences* of an error about 69 *toises* found in the calculations concerning the spanish meridian arc measured in 1806/1808 by Biot (1774–1862) and Arago (1786–1853). At the end of this campaign, Delambre and others had checked the value of the length of the 1799 *MÈTRE*, in considering the arc from Dunkirk to the Balears. Nothing special was said, at the *Bureau des*

*longitudes* but, the following year, a law is passed on July 4th saying that the 1812 law was abrogated and that, from 1840 January the 1st, the weights and measures in only use will be those fixed in 1799.

On that year 1840, articles were published in some newspapers, about the error previously mentioned by Puissant to the *Académie*. This brings the French Board of longitudes to react. On March 25, 1840 the *Bureau* requested some members to form a commission in charge of redoing the computation for the arc. The result is given, on June 2, 1841, by Largeteau (1791–1857), member of the commission including Mathieu (1783–1875), another astronomer from the Paris Observatory and Daussy (1792–1860), an hydrographer, engineer in chief of the Navy. After discussion the report will be accepted two weeks later. The text is published in the *Connaissance des temps* for the year 1844.

The important part of this fundamental paper is given in French:

L'erreur de calcul que nous venons de signaler n'apportera-t-elle pas, dira-t-on, quelque modification à la longueur du mètre ? La réponse est très facile. — La longueur du mètre a été fixée de manière définitive par la Commission des Poids et Mesures; cette longueur ne pourra ni ne devra être changée. Le principal mérite de l'unité nouvelle consistait dans les opérations très précises qu'on exécuta pour donner les moyens de la retrouver si les étalons venaient à se perdre ou à être détruits. — Si jamais on avait pu avoir l'étrange pensée de faire varier l'unité de longueur au fur et à mesure des progrès de la géodésie, on aurait été contraint de l'abandonner en voyant tant de mesures des méridiens et des parallèles manifester des irrégularités locales très considérables et prouver que le globe en masse n'est pas un solide de révolution...

The more important considerations are the following:

- The length of the *MÈTRE* was fixed with a definitive value by the commission for weights and measures.
- This length would never be modified.
- It is considered that introducing some changes in the reference, every time occurred improvements in geodetic measurements, would be a stupid idea. Such a discussion and formulation, the year the metric decimal system becomes a binding decision for all the population, was particularly appropriate.

Nowadays we know that it was a very judicious decision. It was followed every time a new realisation of the meter was put into use. The meaning is, that in the limits within the first *MÈTRE* was obtained, and of course all the following ones, is compatible. The length of the *MÈTRE* whatever it is, equal or not to successive measurements, it is always the same but realized with a better accuracy.

## (6) The decimal metric system and the French population

*Préfets* and *vérificateurs des poids et mesures*, as they were called in French, had played in the past an important rôle during decades; in some cases they would have difficulties with their *canne-mètre*, a stick having a length of a meter and other references for weights such as Roman balances.

Being in Roma, as an ambassador for France, in a chapter of his *Mémoires d'Outre-Tombe*, written in 1828–1829, the French writer Chateaubriand (1768–1848) wrote: *Si vous rencontrez un homme qui, au lieu d'arpents, de toises et de pieds, vous parle d'hectares, de mètres et de décimètres, vous avez mis la main sur un préfet.*

From the mid-thirties, the French Government took stronger decisions, calling the *préfets* and the *vérificateurs* to reinforce their verifications. At that time, many old references were destroyed to be sure that they will not more put into use. Periodical checking were made: lengths and weights could be changed due to their large employments.

The *Annuaire du Bureau des longitudes*, the official publication of the French Government from 1795, published (1828) a text concerning the new names for weights and measures together with the corresponding old ones. The same publication had given details, including the dimensions and weights of the new coins, all called *francs*, their sub-multiples being *décimes* and *centimes*, not *décifrancs* and *centifrancs*. Their dimensions and their weights were determined in such a way than a *mètre* could be obtained with a given composition of coins, as employed by Jules Verne (1828–1905) in his book

*Aventures à travers le monde solaire d'Hector Servadac* to get the length of one *mètre*. Similarly one *kilogramme* could be obtained from 40 coins each one being a 5 *francs*, with weight is 5 *grammes*.

Following 1840 people were more against than previously, being up to this time, allowed to use both old and modern units. They do not understand clearly that, indeed, they could be misled by tradesmen, the same for tradeswomen, of course... As soon as 1840 February 11, a satirical newspaper named *Charivari* published a cartoon by Daumier (1808–1879) being comments between two gossips. The first one says that to buy material for a dress she was asked in a foreign language using *mètre*. The second one who wanted 4 *onces* was replied in *grammes* and other such words as *filigrammes* or *programmés*, mixing names she knows, most probably.

A comment came, in 1846 August 8, from Victor Hugo (1802–1885) the French writer: *Le sac de farine pèse mesure de Paris cent-dix-huit livres, cent quarante neuf kilos* (for kilogrammes), *pour parler l'argot légal*. Victor Hugo designed the old weight measure, transformed into the new one, the *kilogramme*, as being in the legal slang.

In the family of one of us an old song was discovered, most probably published by mid-19th century. Its title is *Nouveau tarif des poids et mesures* (The new price-list for weights and measures). Several units are considered. Firstly the singer mixes the name *mètre* with the French verb *mettre*, same pronunciation but the meaning of the last one is to set. Speaking about an amount of money in *livres* she says that the weight measure of the same name having disappeared, the money has to be given in *kilos*. For length she says that, at the butcher, willing to buy three *pieds* of veal (the lower part of its leg), she was given a little bit more than one *mètre* because three *pieds* were more or less equivalent to one *mètre*. Another old unit was the *ligne* now cancelled of course. So, instead of saying in French *pêcher à la ligne*, the new expression has to be 'pêcher au *millimètre*' (a 'ligne' being also the instrument to 'catch a fish'). She also mixes the word *voie*, employed for ordering a volume of firewood, to be replaced by *stère* with *se taire* (pronounced s'taire).

Despite these remarks and comments, from some parts of the population, a large fraction of it, mostly from informations provided in schools, was better informed. The cartesian aspects of the new decimal system was taken as more powerful in many domains. During the second part of the 19th century, the new system will be adopted by 36 countries some of them having considered it before 1850, and some before the French date January 1st 1840.

## (7) Epilog

The decimal metric system became, in 1960, the base of the *Système international d'unités* (acronym SI) adopted at the international level under the BIPM (Bureau international des poids et mesures, international bureau for weights and measures). This *Bureau* is located in the town Sèvres, situated close to the limit of Paris; the building where it is installed, from 1876, is the Pavillon de Breteuil, situated in the international part of the Parc de Saint-Cloud. From that time, other decisions have been taken at the level of the CIPM (Comité international des poids et mesures, international committee for weights and measures), concerning different rules or decisions tied with all types of measures, writing of numbers, use of dot, comma, multiples, ... Despite these international decisions, rules are not always followed, while taken after long discussions and careful examinations.

On the other hand, even in France where the decimal metric system took birth, old names are still in use, but — of course — not for the old units but surviving from the past times. The more surprising is, most probably, the use of *livre*, *demi-livre*, *quart* (pound, half a pound, one quarter of a pound) which are used, in French, for half a *kilogramme*, indeed little less according to its value for weights, *demi-livre* meaning one fourth of a *kilogramme*, and *quart* meaning one eighth of a *kilogramme*. For foreign countries (and in the south of France) it is better and more easy to speak in *grammes*, *déca-grammes*, *hectogrammes*.

Nowadays, accustomed to the decimal metric system, it is not out of interest to read some reactions of people. As early as 1798 December 31, Zach (1754–1832) had written to Lalande: *Je suis bien fâché que les mesures de Delambre et Méchain aient si mal réussi. Je me garderai bien d'en publier quelque chose dans mes Ephémérides, mais j'espère toujours qu'on conciliera les résultats*. The informations about difficulties were very rapidly known outside the commissions gathered in Paris. A few months later, on 1799 April 29, the same Zach wrote to Lalande: *Je ne parle plus du mètre dans*

*mon Journal, car on commence furieusement à ridiculiser cette réforme, et la nouvelle mesure qu'on nomme la mesure de la Tour de Babel. J'attendrai que l'Institut ait décidé.*

The difficulties, so mentioned, were mostly related to the fact that from the Delambre and Méchain's measurements the flatness of the Earth was found to be 1/150 while, in using the values obtained in Peru by Bouguer (1698–1758) and others, it was estimated at 1/333. This information was mentioned, by Lalande to Flaugergues, on 1799 May 5, while on the 1st of February he had written to a lady friend of him *un secret: une irrégularité de la Terre.*

But, at the same time, exemplars of *mètres* for references were requested from several countries. As examples, the Russian asked for one *mètre* to perform geodetic measurements on the coast of the White Sea (1799); the following year, the same reference was needed in Stockholm, ... On the other hand it is remembered that Lalande, in 1790, had written: ... *il faudra toujours revenir à un étalon convenu, dont les copies exactes, répandues dans la France et dans les Etats voisins seront l'objet de la convention générale, ....* It's exactly what happened with the definitive length of the *MÈTRE* being 3 *pieds 11.296 lignes* of the *Toise du Pérou*. This *toise* was the reference employed, in the equator region by the French expedition to Peru, and by Delambre for comparison with the rulers used to measure the bases of the triangulation. This *toise* is in the Collections of the Paris Observatory together with the four Lavoisier-Borda rulers and the manuscripts of the metric system.

Facing the difficulties, encountered with the decimal metric system during the 19th century in France, is it a dream to consider that its general use will come within the 21st century?

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