Chapter 3
Metrication in France and Beyond: The Meter Goes International

Abstract Adoption of the new metric measures was slow even in France. Compulsory use was resisted and concessions were made that restored some of the names and divisions of older French customary units. The system developed in the 1790s took firm hold in France only after 1840. It was gradually adopted in other nations as well. In 1875 the Metre Convention established institutions that put the metric system under international governance.

3.1 Metrication in Post-revolutionary France

The *Oxford English Dictionary* defines metrication as "conversion to the metric system of weights and measures; the adoption of the metric system." It traces the word back only to 1965 as a coinage by the British National Physical Laboratory—after consultation with an Oxford dictionary editor no less [1]. The term has been used extensively in the UK and the US in connection with those countries' moves toward the metric system. (The adoption of the metric system in the UK was announced in 1965.) The word will be used here to describe similar phenomena, albeit a century and more before the term was coined.

Many historians of the metric system report that the new measures were widely resisted, in commerce at least, from the time of their introduction. John Heilbron reports that a law requiring the new measures to be used in land transactions and building contracts complicated the work of artisans, who would take measurements and buy supplies in old units and convert to new measures for official paperwork [2]. Even the Paris bureau of weights and measures sometimes reverted to the old measures, such as when one of its invoices gave the weight of a shipment of metric standards in pounds [3].

Ken Alder attempted to understand the reasons for the failure of French artisans and merchants to adopt the measures that were, after all, designed in response to complaints from that very group about the old units. He argues that the reforms that French citizens were given were not the reforms they asked for. Uniformity of weights and measures was their principal demand. Savants added several aspects to that demand, particularly after the Académie was formally charged with working to

C. J. Giunta, *A Brief History of the Metric System*,
History of Chemistry, https://doi.org/10.1007/978-3-031-28436-6_3

implement the 1790 decree on the subject. In particular, selecting a standard from nature, making the units relate to each other, making divisions and multiples decimal and inventing a systematic nomenclature were aspects of the reform that appealed to the savants [3]. (Recall that a standard from nature was already part of the 1790 presentation of Talleyrand, which was the basis for the 1790 decree; however, that presentation was apparently influenced by Académie members. See Sects. 2.2 and 2.3.) In light of the intimate involvement of the French scientific establishment in the development of the new units, it should come as no surprise that most branches of French science adopted them quickly. By the time the report on definitive metric units was presented to the *Institut de France*, metric units were already routinely used there [4].

The expression of multiples or divisions of units as powers of 10 was intended to make calculations involving the new units simpler by permitting measures to be expressed as a single number. As an illustration, what is the area of a rectangular piece of cloth 1 yard, 2 feet and 3 inches wide by 3 yards, 2 feet and 1 inch long? If I had to make the calculation, I would express the sides of the rectangle in a single unit, and I would choose inches to avoid fractions. After converting the length and the width to inches, I would multiply them together to get the area in square inches. More arithmetic is needed if the result is desired in square feet or square yards. In metric units, though, even if given a measurement as 1 m, 2 dm and 3 cm, it is trivial to express the measurement as a single number: 1.23 m or 123 cm. The calculation of area amounts to expressing the length and the width in the unit desired for the final answer and simply multiplying the two numbers. We were introduced to this convenience of decimals in Sect. 1.2.

There is an inconvenience of decimal divisions, though, in common operations of simple commerce, where a commodity might have to be divided in half or in thirds or in quarters. Division of a decimal unit by three results in repeating decimals, and every division by two requires an additional decimal place. A dozen (or a 12-inch foot or a 12-oz troy pound) can be divided into halves, thirds, and quarters easily. It is not difficult to imagine accountants preferring decimals but salespeople preferring duodecimal divisions.[1]

Alder did more than point out why some aspects of the reforms left people dissatisfied; he also argues that the old measures fit some aspects of economic activity, in particular labor: "Indeed the whole thrust of the metric reform was to replace an economic system based on value, with one in which everything—human labor, as

[1] In fact, a system that combines the notational and computational ease of decimals with the richness in divisors of dozens was at least broached to the Académie and in the Committee of Public Instruction in the early 1790s [3]. This would involve base twelve arithmetic, in which the numbers zero through eleven would be represented by single digits, for example 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, χ and ε. Beyond single digits, the leading digit in a two-digit number represents twelves place, just as that digit in our familiar base ten system is tens place; thus twelve is represented by 10. The leading digit in a three-digit number represents twelve squared, in a four digit number, twelve cubed, just as in base ten they represent ten squared (a hundred) and ten cubed (a thousand) respectively. Fractions would be represented by places to the right of a divider—called a dozenal point rather than a decimal point. The first place to the right represents twelfths, the next 1/(twelve squared), etc.

well as its artifacts—was translated into the single, paramount variable of price" [3]. For example, land in some localities was harder to clear than in others, so the area of land that could be cleared in a day's work was different. Under this analysis, even uniformity using familiar families of units (for example, imposing Parisian units nationwide) would have met with resistance.

The Consulate (as the French government of the time was called) did not take long to countenance "translations" of the names of the new units. An order on the implementation of the new system of weights and measures issued in November 1800 (11 months after the law on the definitive standards) had two main provisions. It would make the new system mandatory throughout the country the following year, on the first day of year X (known as September 1801 elsewhere in the world), and it would permit the new units to be called by old familiar names in public acts. Thus, for example, a kilogram could be called a pound, a hectogram an ounce; a kilometer a mile, a centimeter a finger, and a millimeter a line [5]. Certainly the names of the units would be familiar. The effect of the law—to the extent that it was followed—would have been to change the values of many familiar units. A pound would weigh about twice as much, a mile would shrink to 5/8 of its former size.

The retreat from ill-received rational decimal systems continued over the next decade. As noted in the previous chapter, a concordat with the Roman Catholic church permitted the lapse of the 10-day *décade* in 1802, and France returned to the Gregorian calendar on 1 January 1806. Early in 1812, a decree countenanced a near total retreat from metric units. The decree begins "There will be no change to the units of weights and measures of the empire." But it goes on to approve multiples and divisions of those units that would best meet the needs of the people, and it calls on the ministry of the interior to make available instruments that read in both the legal (metric) measures and older customary measures [6]. In 1816, after the second restoration of the monarchy, the metric system was abolished for everyday business. Not until the 1830s did the system seem like a good idea again, and it was once again the compulsory system of weights and measures beginning in 1840 [3]. In July 1837, a law was passed permitting metric units with non-decimal divisions (something along the lines of the 1812 law) until 1 January 1840. On that date, the decimal metric system as spelled out in 1795 and 1799 would become the only legal system of weights and measures [7].

This time a commemorative medal (Fig. 3.1) *was* struck. The medallion called for in 1799 was never made, although the *Institut de France* specified the iconography at the time: the obverse would show an allegorical figure representing the French republic, standing on a 5-cm plinth, holding a decimally divided meter standard in one hand and a kilogram in the other; the reverse would feature a globe spanned from pole to equator by the points of an open compass [8].

Fig. 3.1 Medallion commemorating the invention and readoption of the metric system in France, 1840

3.2 Metrication Beyond France, 1851–1875

Few nations outside France adopted the metric system in the first half of the nineteenth century. The first spread was with Napoleon's armies, and some occupied nations readopted the system fairly quickly after the fall of the Empire [9]. The United Kingdom of the Netherlands, which encompassed Belgium and Luxemburg as well as the present-day Netherlands, was the first adopter outside France [10]. Portugal adopted a slightly disguised metric system in the 1810s, taking 1/10 m as its length unit and adopting names of Portuguese customary units rather than the French nomenclature [11]. Only the Kingdom of Sardinia (also known as Piedmont-Sardinia) and nominally Spain followed voluntarily before mid-century [9]. The qualifier "voluntary" excludes imposition of the system by a colonial power on its colonies.[2] France had exported the metric system to its colonies in Algeria and Senegal in 1840. Hector Vera notes that the role of colonialism has often been overlooked in studies of metrication. He writes that both colonialism and decolonization played significant roles in spreading the metric system around the world: former colonies into which the metric system had been introduced invariably retained it upon independence, while others (principally former British colonies) often adopted it upon independence [10].

The 1850s and 1860s saw the first voluntary adoptions of the metric system outside Europe. Nine Latin American nations made the metric system their official measures, beginning with New Granada (now Colombia) in 1853, followed over the next 15 years by Mexico, Venezuela, Brazil, Peru, Uruguay, Chile, Ecuador, the Dominican Republic and (in 1868) Bolivia. Vera notes that this large group of

[2] In the context of this chapter, voluntary refers to a free choice of a sovereign government in contrast to a colonial or other occupying force. In the context of Chap. 6, voluntary refers to the free choice of a business or other user of measures in contrast to legal compulsion imposed by the sovereign government in which the business operates.

adopters, often ignored in studies of metrication, for the most part wished to imitate European nations, but often preceded them [10].

Back in Europe, the Great Exhibition of 1851 in London was an important spur to interest in the system. The exhibition brought a great variety of goods into close proximity in a place where large numbers of scientists, statisticians, engineers, manufacturers and others could see them and notice the international diversity of measures in which they were denominated. This was particularly inconvenient for judges of various types of exhibits. The French display included a set of metric standards exhibited by the *Conservatoire des Arts et Métiers*—a potential solution to the babel of measures. Metric advocates sprang up in many nations in the next few years. The international exposition in Paris in 1855 had similar effects [9].

The International Statistical Congress advocated for metric units over the next decade. The first Congress, meeting in Brussels in 1853, urged governments reporting figures to include conversions to metric units. By 1860, the Congress voted for its members to urge adoption of the metric system in their own nations. Advocates for international uniformity in weights and measures formed an international association in the mid-1850s, soon establishing branches in 15 countries. Before the end of the decade, that association was urging adoption of the metric system [9].

The British branch of the association lobbied for adoption of the metric system, and in 1863 the British Association for the Advancement of Science joined it. The House of Commons passed a metric bill in 1863, too late to be acted on by the House of Lords. It looked as though the UK, the world's leader in trade and industry, was soon to adopt the system, and that in itself encouraged other nations to do the same [9]. The following year the UK passed a law legally permitting the metric system in contracts, but not in ordinary commerce [12].

Not all of the British scientific establishment favored the metric system. In 1863, Sir John Herschel (1792–1871) suggested that if a system of measures was to be adopted internationally for the promotion of trade, it ought to be the British imperial system, which was already more widely diffused. The Astronomer Royal of Scotland, Charles Piazzi Smyth (1819–1900) was the most prominent (but not the only) proponent of the idea that the Great Pyramid was a divinely inspired standard of measure at the root of British customary measures [13]. Movement of the British toward adopting the metric system was effectively derailed after a Standards Committee issued its second report on the matter in 1869. It found that the nation was not ready for such a conversion and that the superiority of metric to imperial units had not been demonstrated [9].

The metric system was also under consideration in the other large English speaking nation, the United States. Its National Academy of Sciences (founded in 1863) studied weights and measures and recommended the metric system in 1866. Later that year a law was passed that permitted, but did not require, use of the metric system in legal transactions [9]. (Metrication in the US is the subject of Chap. 6.) Two newly unified European nations adopted the metric system in the 1860s, as signs of national uniformity. These were Italy in 1861 and Germany in 1868 [10].

Interest in internationally uniform weights and measures was manifested in several events of 1867. That year's "Universal Exposition" in Paris had an exhibition on weights, measures and currency, including displays from around the world—not just around Europe. Among the exhibitors were Brazil, China, Egypt, Japan, Morocco, Turkey, the US and several other (unspecified) African, Asian and South American states [14]. Its pavilion was in the center of the grounds, inscribed with the words "Omnia, o Deus, fecisti ex numero, mensura et pondere" [15].[3] An international conference on the subject was held in conjunction with the exposition. Its delegates nearly unanimously declared that the metric system was best suited for use in industry, commerce and science [14].

Other international technical societies endorsed the metric system in 1867. The sixth International Statistical Congress called for its members in non-metric countries to form associations to lobby for metrication. The new International Geodetic Association endorsed the metric system for use in geodesy and called for an international commission to construct new metric standards [9]. Coming from an organization that grew out of a central European surveying project in which France had little involvement and Prussia much, this call prompted action in France to ensure that it would have a prominent role in any internationalization of the metric system [16].

In 1869 a committee of the French Académie des sciences reported to the full Académie its opinion that the meter and the kilogram were defined by the standards made in 1799 rather than by the abstract definitions that those standards were intended to embody. It proposed that the government invite other nations to form an international commission to decide how to make and disseminate copies of the standards to nations that wished to adopt the metric system [17].

The French government proceeded to invite other states in Europe and the Americas to appoint delegates to an International Commission of the Meter to meet in Paris in 1870. The Commission did meet on August 8–13, a few weeks after the start of the Franco-Prussian war. On the first day, some of the foreign members suggested (uncontroversially) that no firm decisions be made until the missing nations (Prussia and North German states) could be at the table. More controversially, they suggested that their job was to construct an international prototype of the meter, whereas they had been invited to work on making legal copies of the existing standard in the French Archives. They also wanted to expand the commission's scope to the entire metric system and to satisfy the needs of modern science. These goals were, after some discussion, adopted unanimously (including by a representative of the French government). The commission also agreed that the definition of the meter needed to be an artifact rather than a theoretical definition, whose experimental embodiment might be expected to change as science progressed [16].

The brief session of 1870 laid useful groundwork for the next meeting of the Commission in 1872. That meeting concerned itself with the kilogram as well as the meter. The question of whether to define the kilogram going forward on the theoretical definition of a cubic decimeter of water or the existing standard of the archives was debated and eventually resolved in favor of the artefact. The appeal of the theoretical definition was that it made the system connected, the weight standard

[3] "You have made everything, O God, from number, measure, and weight." See Wisdom 11:20—in some editions 11:21—in a Catholic Bible or a Protestant one that includes apocrypha.

depending on the length standard. Those who favored this connection recognized that defining the unit by the artefact was simpler and they were eventually convinced that the existing artefact embodied the desired relationship to sufficient accuracy. An alloy of platinum containing 10% iridium was selected as the material for making new standards of both units. The Commission also took some steps toward building longer-term institutions. It selected a Permanent Committee of 12 members, each from a different state. And it recommended founding an international bureau of weights and measures [16].

3.3 The Metre Convention of 1875 and the International Prototypes

Representatives of 20 states from Europe and the Americas met in Paris during spring 1875 at a conference that resulted in the Metre Convention. The participants included diplomats authorized to commit their countries, as well as special delegates versed in technical matters. The diplomatic conference appointed a special commission to resolve outstanding scientific matters before proceeding to government action. Jean-Baptiste Dumas (1800–1884), a highly respected chemist with some governmental experience, presided over the special commission [16]. Dumas had served on the Académie committee mentioned in the previous section tasked with considering the status of metric standards [17].

The treaty established institutions that continue to function today as custodians of the metric system and its expanded version, the International System of Units (*Système international d'unités*, SI). It established the International Bureau of Weights and Measures (*Bureau international des poids et mesures*, BIPM), sited near Paris, which would carry out metrological work involving the metric standards. The bureau was housed in France, but it was to function as an international body under the direction of an International Committee of Weights and Measures (*Comité international des poids et mesures*, CIPM). The CIPM itself operated under the authority of the General Conference of Weights and Measures (*Conférence générale des poids et mesures*, CGPM), comprised of representatives of the signatory nations, which would meet every few years [18]. The text of the treaty was signed initially in April 1875, and the CIPM was immediately constituted. The treaty was formally signed a few weeks later by 17 of the 20 nations represented at the conference (Table 3.1 lists the nations represented at the 1875 conference, the original signatories of the Metre Convention and the nations that had adopted the metric system by 1875.) The three nations at the conference that did not sign at the time were—in the order in which they subsequently joined the convention—the United Kingdom (1884), the Netherlands (1929) and Greece (2001). Among the original signatories was the United States. (Adhering to the Metre Convention does not imply adoption of the metric system, or vice versa; the Convention is about international institutions of standards and metrology.) The treaty has been modified since its adoption, but not since 1921 [16].

Table 3.1 International metric engagement in 1875

Attended 1875 metric conference [16]	Signed metre convention [16]	Adopted metric system [10]
Argentina	Argentina	Austria-Hungary
Austria-Hungary	Austria-Hungary	Belgium
Belgium	Belgium	Bolivia
Brazil	Brazil	Brazil
Denmark	Denmark	Chile
France	France	Colombia
Germany	Germany	Dominican Republic
Greece	Greece	Ecuador
Italy	Ottoman Empire	France
Netherlands	Peru	Germany
Ottoman Empire	Portugal	Italy
Peru	Russia	Liechtenstein
Portugal	Spain	Luxembourg
Russia	Sweden and Norway	Mexico
Spain	Switzerland	Monaco
Sweden and Norway	United States	Montenegro
Switzerland	Venezuela	Netherlands
United Kingdom		Ott
United States		oman Empire
Venezuela		Peru
		Portugal
		Romania
		Serbia
		Spain
		Sweden and Norway
		Switzerland
		Uruguay
		Venezuela

The first CGPM met in September 1889, after a batch of standards for both the meter and the kilogram had been made and compared. International prototypes were selected from among them, thenceforth defining the meter and kilogram. Nations adhering to the Convention received their national prototypes [16].

One century after the calls for uniform weights and measures across France were delivered to the Estates general of 1789, the system invented in response to those calls was embodied by new standards under international governance. The metric system had taken root in many territories outside its place of birth, and it was favored by many transnational organizations.

References

1. OED Online (2022) Metrication, n. Oxford University Press, https://www.oed.com/view/Entry/117666. Accessed 7 Nov 2022
2. Heilbron JL (1989) The politics of the meter stick. Am J Phys 57(11):988–992

3. Alder K (1995) A revolution to measure: the political economy of the metric system in France. In: Wise MN (ed) The values of precision. Princeton University Press, Princeton, NJ, pp 39–71
4. Gillispie CC (2004) Thermidorean convention and directory. Science and polity in France: the revolutionary and Napoleonic years. Princeton University Press, Princeton, NJ, pp 445–550
5. Duvergier JB (ed) (1834) Arrêté relatif au mode d'exécution du système décimal des poids et mesures, 13 brumaire an IX [4 Nov 1800]. In: Collection complète des lois, décrets, ordonnances, règlements avis du conseil-d'état, 2nd edn, vol 12, A. Guyot et scribe, Paris, pp 329–331
6. Duvergier JB (ed) (1834) Décret concernant les poids et mesures, 12 Feb 1812. In: Collection complète des lois, décrets, ordonnances, règlements avis du conseil-d'état, 2nd edn, vol 18. A. Guyot et scribe, Paris, p 119
7. Duvergier JB (ed) (1837) Loi relative aux poids et mesures, 4 Jul 1837. Collection complète des lois, décrets, ordonnances, règlements avis du conseil d'état, vol 37, Pommeret et Moreau, Paris, pp 164–173
8. Bigourdan G (1901) Le système métrique des poids et mesures: son établissement et sa propagation graduelle, avec l'histoire des opérations qui ont servi à déterminer le mètre et le kilogramme. Gauthier-Villars, Paris, pp 179–180
9. Cox EF (1958) The metric system: a quarter-century of acceptance (1851–1876). Osiris 13:358–379
10. Vera H (2011) The social life of measures: metrication in the United States and Mexico, 1789–2004. Dissertation, New School
11. Paixão F, Jorge FR (2006) Success and constraints in the adoption of the metric system in Portugal. In: Kokowski M (ed) The global and the local: the history of science and the cultural integration of Europe. Proceedings of the 2nd ICESHS (Cracow, Poland, 6–9 Sept, 2006), pp 463–470
12. Tavernor R (2007) Anglo-Saxon resistance. Smoot's Ear: the measure of humanity. Yale University Press, New Haven, CT, pp 118–147
13. Schaffer S (2008) Metrology, metrication, and Victorian values. In: Lightman B (ed) Victorian science in context. University of Chicago Press, Chicago, pp 438–474
14. Levi L (1868) Report of the International conference on weights, measures, and coins held in Paris, June 1867. Harrison and Sons, London
15. Fuchs E (1887) Notice nécrologique sur M. A.-E. Béguyer de Chancourtois, Inspecteur général des mines. Ann Mines 11:505–536
16. Quinn TJ (2012) From artefacts to atom: the BIPM and the search for ultimate measurement standards. Oxford University Press, Oxford
17. Dumas JAB et al (1869) Rapport sur les prototypes du système métrique: le mètre et le kilogramme des Archives. C R Séances Acad Sci 69:514–518
18. BIPM (1991) Metre convention and annexed regulations—authoritative French text, with English translation (1876). https://www.bipm.org/documents/20126/44107685/metre-convention.pdf. Accessed 7 Nov 2022