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The Federal Move to Metric: Public Law, DoC and NIST

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Introduction

Since its initial development, the metric system of measurement has evolved to become the modern International System of Units (SI) and been formally accepted by all the nations of the world save three and all the industrialized nations save one, the United States.

During the period from introduction of the metric system in 1790 to the present, the U.S. Congress — with its Constitutional power to fix the standards of weights and measures for the nation — has at least five times given major consideration to conversion of the U.S. from its customary system to metric, each time choosing not to require change. Most recently, Congress passed the "Metric Use" provisions of the Trade and Competitiveness Act of 1988, including amendments to the Metric Conversion Act of 1975, and does now require: 1) Federal agencies, including the Department of Commerce and de facto its operating units such as the National Institute of Standards and Technology, to plan and implement conversion to use of metric units in their business-related activities; and 2) the Department of Commerce to provide coordination of Federal agency conversion through interagency committees and other actions.

This paper reviews briefly the Federal legislative history of metric use in the U.S., metric practice associated with the modernized system, and the policies and plans of the Federal government in its legislatively-mandated conversion to use of that system.

Legislative History of Metric in the U.S.

The metric system is a system of measurement units originally consisting of the meter as the basic unit of length and the kilogram as the basic unit of mass initially developed by the French National Academy of Sciences at the behest of the French National Assembly in 1790. The metric system was established as an international system of standards by the Treaty of the Meter of 1875 to which the United States was a signatory.

The system of measurements in use throughout the U.S. from the founding of the republic in 1789 to the present, however, is in the main a derivative of the old British system based on a yard and pound which at various times Congress has considered abandoning in favor of the international metric system. Table I outlines some of the principal Federal legislative and administrative actions on metrication, the process of conversion to use of the metric system [1].

With its ratification in 1789, the Constitution delegated to Congress the power "to fix the standards of weights and measures" for the United States. In 1817, Congress requested the

Table I History of Federal Actions on Metrication in the U.S.

1789	Constitution	Delegates Congress power "to fix the standards of weights and measures"
1817	Congress	Requests Sec State to recommend system of weights & measures among the states
1828	Mint	Adopts Troy pound as basis of coins
1832	Treasury	Adopts yard, avoidupois pound and Winchester bushel as basis of customs duties
1866	Congress	Makes use of metric measurements legal in contracts
1870	State	U.S. signatory to "Treaty of Meter" establishing meter and kilogram
1893	Treasury	Announces yard and pound to be derived from U.S. prototype meter and kilogram
1894	Congress	Enacts law establishing electrical units based on metric system
1895	Congress	Adopts but does not implement resolution to study adoption of metric system
1950s	Army	Establishes linear metric units for weapons
1960s	FDA	Pharmaceutical industry converts to metric
1970s	BATF	Requires metric containers of wine & spirits
1968	Congress	Calls for three-year study of use of metric ystem
1971	DoC	Provides Congress "Metric America" report
1975	Congress	Authorizes U.S. Metric Board to foster voluntary conversion
1982	Executive	Abolishes U.S. Metric Board and transfers residual function to DoC
1988	Congress	Designates metric *preferred* system for U.S., *mandatory* for Federal agencies
1990	GAO	Reports to Congress that Federal agencies not acting
1991	Executive	Issues executive order to Federal agencies in line with 1988 Congressional act
1992	Agencies	Develop date-certain plans for use of metric in all business-related activities

Secretary of State to recommend a uniform system of weights and measures to be used among the states. Then Secretary of State John Quincy Adams, after a thorough, three-year study produced a major study and analysis of measurement systems — including the French meter-based system — which recommended retention of the British-based system in customary use. Congress received the report without passing legislation.

In 1828, however, the U.S. Mint had by administrative action adopted the Troy pound as the basis of coinage and in 1832, on the same basis, the U.S. Treasury adopted the yard, the avoirdupois pound and the Winchester bushel as the basis of customs duties.

In the 1860s, in addition to passing bills abolishing slavery, providing Federal land for the right of way of a transcontinental railroad, and establishing an agriculture department and land-grant colleges, Congress in an 1866 act legalized the use of the metric system in the United States and set approximate equivalents between customary and metric measures.

In 1875, the U.S. — one of nineteen nations — signed the international "Treaty of the Meter" which in providing for construction of standards for the meter and kilogram and establishing an International Bureau of Weights and Measures (CGPM) created the metric system, the official international system of weights and measures recognized as such by most of the major commercial and scientific nations of the Western Hemisphere.

In 1893, subsequent to receipt in 1890 from CGPM of the U.S.'s prototype meter and kilogram, the Superintendent of Weights and Measures by an administrative action with the approval of the Secretary of the Treasury declared these specific artifacts to be the nation's "fundamental standards" of length and mass.

In 1894, Congress passed laws defining electrical units based on the metric system and in 1895 studied the feasibility of adoption of the metric system by the U.S. but with opposition within and without did not act to do so.

For the seventy-five year period from 1893 to 1965, various Federal agencies took specific administrative actions regarding use of metric units in their own mission areas. For example, in the 1950s the U.S. Army established linear metric units for its weapons and related systems and in the 1960s the FDA oversaw the conversion of the pharmaceutical industry to metric. In the early 1980s the Federal Bureau of Alcohol, Tobacco and Firearms required packaging of wines and spirits in metric-sized containers [2].

The cumulative effect of these various Federal legislative and administrative actions with respect to standards of measurement is a very heterogenous system, the character of which is suggested by Table II which shows examples of electrical quantities, mass, length and volume in use. As Table II shows, the overall system of measurements in use in the U.S. involves: metric units for electrical quantities such as the ampere, volt and ohm; two different pounds - Troy and avoirdupois; the yard as the "fundamental unit" of length, with two different types of feet as its submultiple - the U.S.-international foot and the U.S. survey foot; and the Winchester bushel for volume, with two different types gallon, quart and pint for dry and liquid measure.

Table II Some Elements of the Current U.S. System of Measurements, Implied By Various Federal Legislative and Administrative Actions, and Their Relation to SI Units

Quantity	*Unit*	*Basis*	*Conversion Factor*	*SI Unit*
Electricity	Ampere	SI	1	A
	Volt	SI	1	V
	Ohm	SI	1	Ω
Mass	Pound #1	Troy	0.337 241 7	kg
	Pound #2	Avoirdupois	0.453 592 4	kg
Length	Yard	Yard	0.914 4	m
	Foot #1	= 1/3 Yard	0.304 8	m
	Foot #2	Survey Foot	0.304 800 6	m
Volume	Bushel	Winchester	$3.5\ 239\ 07\ 10^{-2}$	m^3
	Pint #1	Dry	$5.506\ 105\ \cdot 10^{-4}$	m^3
	Pint #2	Liquid	$4.731\ 765\ \cdot 10^{-4}$	m^3

The Most Recent Moves of the Congress Toward Metric Use

For nearly twenty years beginning in the late 1960s, Congress again took up the issue of conversion of the U.S. system of measurements as a whole. In 1968, Congress initiated a three-year study of the use of the metric system for the U.S. In response, in 1971 the Department of Commerce's National Bureau of Standards provided Congress a "Metric America" report which lead in part to establishment by Congress in 1975 of a U.S. Metric Board in the Executive Branch to promote voluntary conversion of the U.S. to metric [1]. In 1982, the Executive Branch abolished the U.S. Metric Board and transferred the residual function to DoC. The latest move by Congress toward metrication began four years ago [3].

In 1988, in the "Metric Use Act of 1988," part of the "Omnibus Trade and Competitiveness Act" of that same year, Congress designated the modernized metric system as the *preferred* system of measurement for the U.S. and made use of metric units mandatory for Federal agencies in their procurements, grants, and other business-related activities. According to a Congressional General Accounting Office report in 1990, Federal agencies were then doing little to nothing in implementing the terms of the law. Subsequently, the President issued an Executive Order directing Federal agencies to do so, particularly to develop and implement the date-certain plans for use of metric according to the terms of the 1988 law [4].

The Evolution of the "Modernized Metric System"

Designated by Congress as the preferred system of measurement for U.S. trade, commerce and industry, the metric system of today is "the modernized metric system," formally the International System of Units (SI). As indicated in Table III, what is most appropriately referred to as "the modernized metric system" is the result of an evolution underway since the metric system was first established [1,5].

Table III Principal Events in the Development of the International Systems of Measurements (SI), the Modernized Metric System

1790	French National Assembly requests French Academy of Sciences to work out a system of weights and measures suitable for the whole world
	France adopts meter (1) and kilogram (2) as units of mass and length
1870	International Treaty of Meter establishes m and kg as international standards, Sets up International Bureau of Weights and Measures (CGPM)
1881	Intl Electrical Congress establishes CGS (centimeter-gram-second) system (3)
1900	Mechanical measurements based on MKS (meter-kilogram-second) system
1935	Mechanical & electrical linked by addition of ampere in MKSA system (4)
1954	CGPM establishes SI (International System of Units):
	Rationalizes units of MKSA system (1-4)
	Adds degree kelvin as the unit of temperature (5) and candela as the unit of luminous intensity (6)
	Designates prefixes for multiple and submultiple units
1971	CGPM adds mole as base unit (7)
1975	CGPM adds prefixes for multiples and submultiples of powers of 15 and 18
1991	CGPM adds prefixes for multiples and submultiples of powers of 21 and 24

In 1790, the French National Assembly requested the French Academy of Sciences to work out a system of weights and measures suitable for the whole world. As a result of the Academy's work, France adopted the first and second of today's base units, the meter and the kilogram, as the standard units of length and mass respectively.

In 1875, the International Treaty of the Meter (with, as mentioned above, the U.S. as a signer) established the meter and kilogram as international standards, setting up the International Bureau of Weights and Measures (CGPM) to fabricate new prototypes of each for themselves and the participating nations.

Over the next sixty years, separate metric systems evolved in two different fields which were subsequently joined and became the basis for the modernized system. In 1881, the International Electrical Congress in effect expanded the metric system by adding a third base unit, the second for time, to create the centimeter-gram-second (CGS) metric system for electrical measurements. In 1900, in practice, mechanical measurements had come to be based on a parallel, meter-kilogram-second (MKS) metric system. In 1935, the electrical and mechanical metric systems were linked by the addition of a fourth base unit, the ampere (A) for electrical current, to produce the MKSA system.

In 1954, the International Bureau of Weights and Measures established the International System of Units (SI) by: rationalizing the relations of the four base units of the MKSA system; increasing the number of base units to six with addition of the degree Kelvin for temperature and candela for luminous intensity; and designating prefixes for the multiples and submultiples of the units. In 1971 CGPM added the seventh base unit, the mole, in 1975, added prefixes for multiples of 10^{15} and 10^{18}, and in 1991 completed the present "modernized metric system" by adding further prefixes for multiples and submultiples of 10^{21} and 10^{24}.

World-Wide Adoption of the Metric System

In parallel with the technical evolution of the modernized metric system and the legislative history of study and non-adoption of the metric system in the U.S., lead by the industrialized nations the world as a whole has long been moving inexorably toward complete adoption.

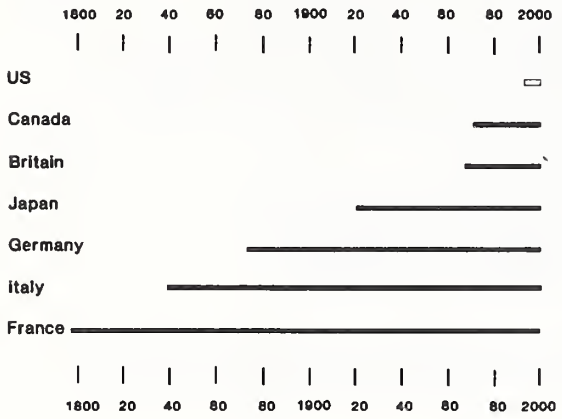

Figure 1 Interval of Years For Which Each of the Group-of-Seven Industrialized Nations Will Have Been Metric At Beginning of Twenty-First Century (US: Federal Agencies Only)

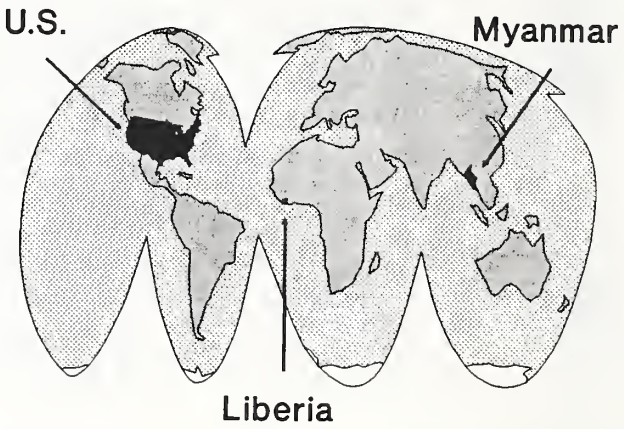

Figure 2 Map of the World Showing the Three Nations - the U.S., Myanmar and Liberia - Which have Not Adopted the International System of Measurements, the Modernized Metric System As of Jan 1992

Figure 1 shows the projected interval of years each of the "group-of-seven" leading industrialized nations will have been metric at the end of this decade. As indicated in the Figure, while Britain and Canada have will have accepted and been using metric units for approximately twenty-five years, Japan fifty, Germany one hundred and twenty five, Italy one hundred and sixty, and France, the originator of the system, over two hundred [1,6,7], under current law the U.S. alone will enter the twenty-first century with industry and society as a whole under no requirement to have used the international system at all.

Figure 2 shows on a world map the two nations other than the U.S. which have not adopted that international system, those two being Myanmar and Liberia. Together three non-metric nations represent less than 3% of the world's population [2].

The Modernized Metric System

As summarized in Tables IV-VIII, the modernized metric system — that is, the International System of Measurements (SI) — in its present form consists of: the seven SI *base units* shown in Table IV; the twenty SI prefixes for multiples and submultiples shown in Table V; the two SI *supplementary units* shown in Table VI; numerous SI *derived units*, examples of which are shown in Table VII; and nineteen SI derived units with special names, seven of which are shown in Table VIII [4].

Note that among the properties of the SI system of measurements are: that there is one and only one unit for each physical quantity; corresponding to each unit there is a unique and well-defined symbol (with spelled-out name and pronunciation independent of user's language); there is decimal relation among multiples and submultiples of the unit for each physical quantity; and the system of units is coherent, that is, the numerical values of units are chosen such that the equations between numerical values, including the numerical factors, have exactly the same form as the corresponding equations between the quantities.

Federal Policy on Use of the Metric System in the U.S.

As written in law passed by Congress and signed by the President, incorporated in the U.S. code, announced in the Federal register, and addressed to Federal agencies by executive order, it is the declared policy of the United States [4]:

(1) to designate the metric system of measurement as the preferred system of weights and measures for United States trade and commerce:

(2) to require that each Federal agency, by a date certain and to the extent economically feasible by the end of the fiscal year 1992, use the metric system of measurement in its *procurements, grants and other business-related activities* (emphasis added)

- except to the extent that such use is impractical or is likely to cause significant inefficiencies or loss of markets to United States firms, such as when foreign competitors are producing competing products in non-metric units;

(3) to seek ways to increase understanding of the metric system of measurement through educational information and guidance and in Government publications; and

(4) to permit the continued use of traditional systems of weights and measures in non-business activities.

Table IV The Seven SI Base Units

Quantity	*Name*	*Symbol*
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Temperature	kelvin	K
Amount of Substance	mole	mol
Luminous Intensity	candela	cd

Table V The Twenty SI Prefixes

Factor	*Prefix*	*Symbol*
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Table VI The Two SI Supplementary Units

Quantity	*Name*	*Symbol*	*In SI Units*
plane angle	radian	rad	$m \cdot m^{-1} = 1$
solid angle	steradian	sr	$m^2 \cdot m^{-2} = 1$

Table VII Examples of SI Derived Units

Quantity	*Name*	*Symbol*
area	square meter	m^2
volume	cubic meter	m^3
velocity	meter per second	m/s
density	kilogram per cubic meter	kg/m^3
luminance	candela per square meter	cd/m^2

Table VIII Seven of the Nineteen SI Derived Units with Special Names Expressed in Base Units

Quantity	*Name*	*Symbol*	*Base Units*
frequency	hertz	Hz	s^{-1}
force	newton	N	$m \cdot kg/s^2$
pressure, stress	pascal	Pa	N/m^2
energy, work, quantity of heat	joule	J	N·m
Celsius temperature	degree Celsius	°C	K
electrical resistance	ohm	Ω	V/A
dose equivalent	sievert	Sv	J/kg

Implementation of Current Federal Policy on Metric Use

For coordinating Federal agencies' conversion to metric in their measurement-sensitive business-related activities and encouraging its use where Federal procurement is not the predominant influence, Congress provided for the establishment of the executive-branch structure shown in Figure 3 [4].

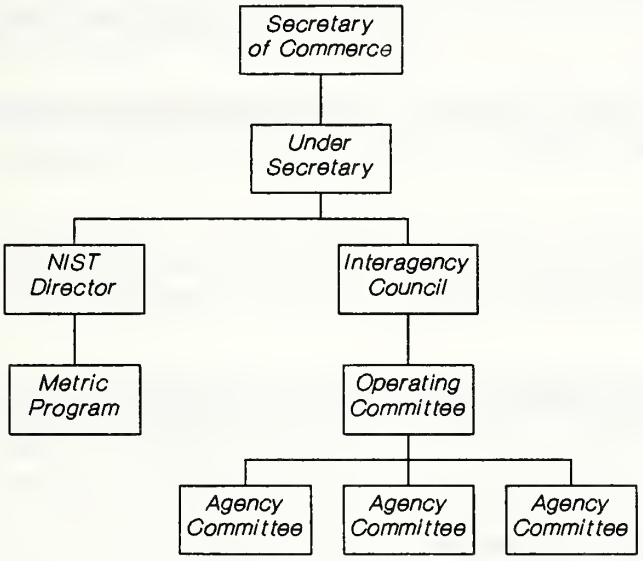

Figure 3 Officials and Committees Responsible for Coordination of Implementation of Federal Agencies' Programs in Metrication Under Terms of the Metric Use Act of 1988

Congress directed the Secretary of Commerce to: appoint an Under Secretary to assist in coordinating efforts of Federal agencies in meeting their new responsibilities under the terms of the Metric Conversion Act; set up an Interagency Council on Metric Policy (ICMP), chaired by the Under Secretary and comprised of senior policy officials designated by the various Federal agencies to be responsible for agency metric policy; and establish a Metrication Operating Committee (MOC) as an interagency working committee reporting to the ICMP.

Also in operation within the DOC providing support to the Under Secretary on coordination of Federal metrication programs is the Metric Program originally established under the 1975 Metric Conversion Act.

As a Federal agency, NIST - which adopted SI units for its technical programs and publications in 1960 - has representatives to the ICMP, MOC, and DoC Metric Committee, as well as its own internal NIST Metric Committee to deal with its program of carrying out conversion to metric in its procurements, contracts, grants, technical publications, storeroom operations, and other business-related activities, as well as providing a technical point of contact on use of SI units [8].

For further information on aspects of the general implementation of Federal policy on conversion to metric, you may refer to publications on SI use by NIST (Refs 4,5) or the American National Standards Institute (Ref 9) or contact the individuals below:

Robert White	Chairman, Interagency Council on Metric Policy 202-377-4625
John Lyons	Director, NIST 301-975-2300
Gary Carver	Head, Metric Program 301-975-5019
Joe Simmons	Coordinator, NIST Metric Program 301-975-2005
Barry Taylor	Technical Contact, NIST, SI Units 301-975-4220

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