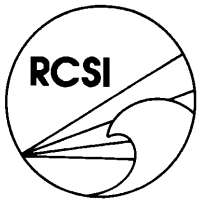

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The Metric System

By: Davis Frederickson & Gerald A. Takacs
August 1975

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The Metric System

by
Davis Frederiksen* and Gerald A. Takacs

Summary

Over ninety-two percent of the world is using the metric system of measurements. The United States is slowly converting to this system in an uncoordinated way. Legislative action would make this change-over more rapid and orderly.

This paper reviews: the metric system, the advantages and disadvantages for converting to the metric system, the legislative attempts at accomplishing this conversion, and some conversions that have already been made.

Introduction

A system of uniform units of measurement is needed to express information quantitatively. There are two systems of units used today: The English or Customary System (although the English began their conversion to the other system in 1965) and the International System of Measurement Units (SI), commonly, although not quite correctly, referred to as the metric system.

The metric system is the dominant language of measurement in the world. Only a few nations have not yet adopted the metric system or decided to do so. Of these, the most notable is the United States. Yet, the United States was the first country to decimalize its currency, in 1793.

Figure 1 shows the advance of metric usage in the world since its origin in France in 1790.

The International System of Units (SI Units)

There are seven base units in the International System of Units and these are listed in Table 1.

Americans are already familiar with the centigrade temperature scale. On that scale, water freezes at 0°C and boils at 100°C under standard conditions. The same scale, now called the Celsius scale, will be retained under the metric system for everyday use. For scientific and engineering purposes the absolute temperature scale will be used (degrees Kelvin, °K), which starts at a much colder zero point, but uses "degrees" of the same size. Consequently, conversion from °C to °K is done by simply adding 273.15 to get to temperature °K.

* Part of this bulletin was completed by Davis Frederiksen as an undergraduate project at Rochester Institute of Technology.

Figure 1. Advance of Metric Usage in the World

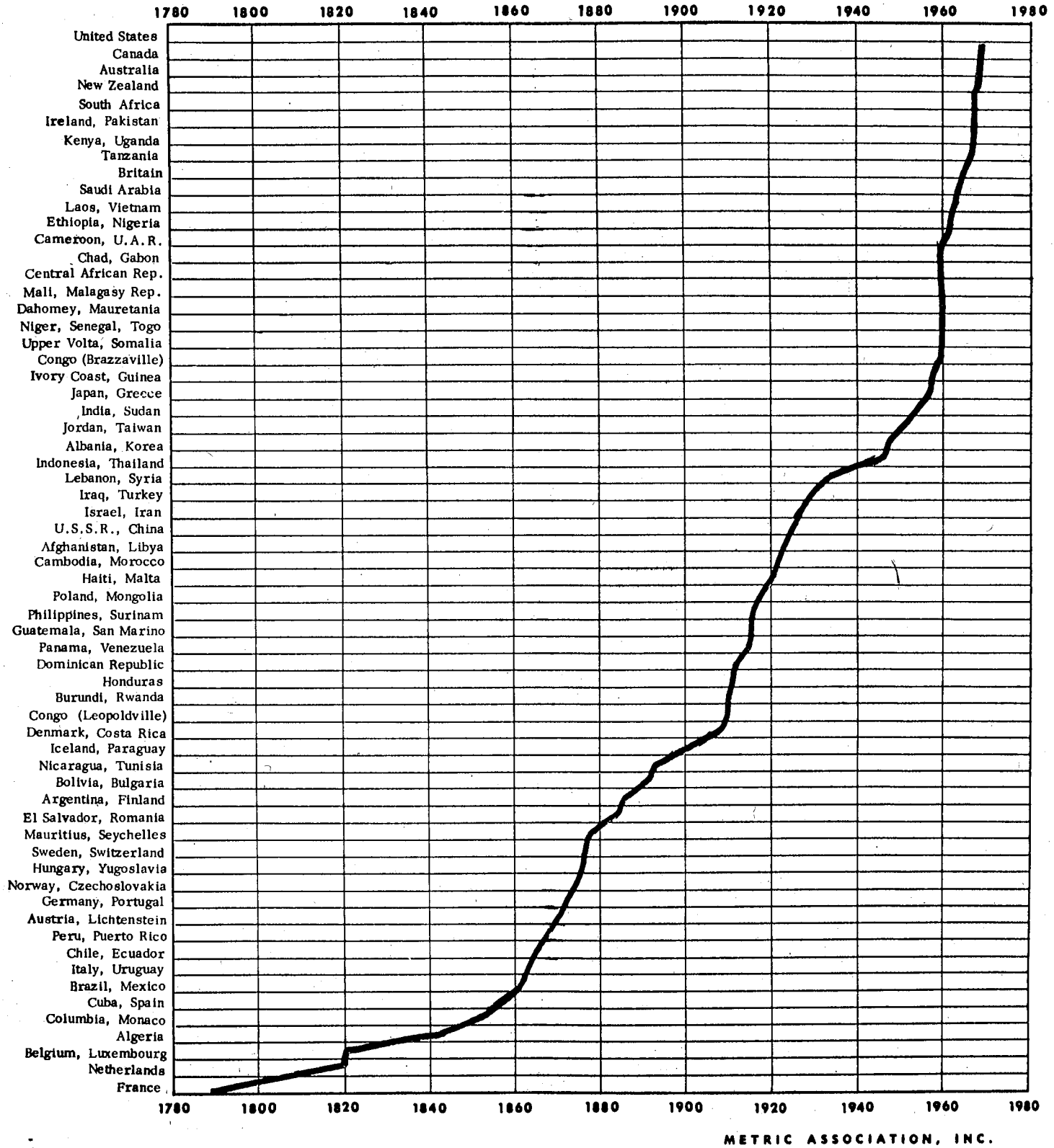

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Table 1. Base Units

Quantity	Name of Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
temperature	kelvin	K
electric current	ampere	A
luminous intensity	candela	cd
amount of substance	mole	mol

These base units can then be used to derive the units for other quantities. For example, the units for area are meter x meter; i.e. m^2. No matter what the size of the base units and the derived units, they will not be convenient for all applications. Therefore a range of multiplying prefixes (associated with the base unit) are necessary in order to adjust the unit to the size required. For example, a millimeter is one thousandth (0.001) of a meter. Table 2 lists these prefixes.

Table 2. Multiplying Prefixes Used with SI Units

Prefix	Symbol	Power		Example
tera	T	10^{12} =	1,000,000,000,000	
giga	G	10^{9} =	1,000,000,000	
mega	M	10^{6} =	1,000,000	
kilo	k	10^{3} =	1,000	kilometer (km)
hecto	h	10^{2} =	100	
deca	da	10^{1} =	10	
deci	d	10^{-1} =	.1	
centi	c	10^{-2} =	.01	
milli	m	10^{-3} =	.001	milligram (mg)
micro	μ	10^{-6} =	.000001	microsecond (μs)
nano	n	10^{-9} =	.000000001	nanometer (nm)
pico	p	10^{-12} =	.000000000001	
femto	f	10^{-15} =	.000000000000001	
atto	a	10^{-18} =	.000000000000000001	

There are a number of units which are used in the metric system which are not base units in the International System and some of these are listed in Table 3.

Table 3. Units Outside International System but Frequently Used With It.

Name	Symbol	Value in SI
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3600 s
day	d	1 d = 24 h = 86,400 s
degree	°	$1^{\circ} = (\pi/180)$ radian
minute	'	$1' = (1/60)^{\circ}$
second	"	$1'' = (1/60)'$
liter	l	$1\ l = 10^{-3} m^3$
tonne	t	$1\ t = 10^{3} kg$
calorie	cal	1 cal = 4.185 joules = $4.185 kgm^2 s^{-2}$

Table 4 shows a conversion from English to metric quantities. Some of the most commonly used units are closely related (a liter is approximately a quart, a meter is approximately a yard, and a kilogram is roughly 2 pounds). Others are less familiar, and application to a gross unit, such as a box of cereal or a bottle of juice is not easy without practice. For precise work, in shop or laboratory, tables are used routinely to convert the units.

Table 4. Approximate Conversions from English to Metric System

When you know:	You can find:	If you multiply by:
Length		
inches	millimeters	25
feet	centimeters	30
yards	meters	0.9
miles	kilometers	1.6
millimeters	inches	0.04
centimeters	inches	0.4
meters	yards	1.1
kilometers	miles	0.6
Area		
square inches	square centimeters	6.5
square feet	square meters	0.09
square yards	square meters	0.8
square miles	square kilometers	2.6
acres	square hectometers (hectares)	0.4
square centimeters	square inches	0.16
square meters	square yards	1.2
square kilometers	square miles	0.4
square hectometers (hectares)	acres	2.5
Mass		
ounces	grams	28
pounds	kilograms	0.45
short tons	megagrams (metric tons)	0.9
grams	ounces	0.035
kilograms	pounds	2.2
megagrams (metric tons)	short tons	1.1
Liquid Volume		
ounces	milliliters	30
pints	liters	0.47
quarts	liters	0.95
gallons	liters	3.8
milliliters	ounces	0.034
liters	pints	2.1
liters	quarts	1.06
liters	gallons	0.26
Temperature		
degrees Fahrenheit	degrees Celsius	5/9(after subtracting 32)
degrees Celsius	degrees Fahrenheit	9/5(then add 32)

Advantages and Disadvantages in Converting to the Metric System

The United States exports to a world which is already 92% committed to the metric system. Common Market countries have demanded that all its imports must meet metric standards by 1978. It must now use a dual system for its domestic market, and packaging with both systems has become common.

The metric system is much more uniform than our present system. With the metric system, in converting from one unit of measurement to another we are concerned only with shifting the decimal point, while the present system requires fractions (e.g. inches to feet).

One disadvantage in converting will be the short term necessity of a dual system of metrics with bushels, pecks, acres, ounces, pounds, dry and liquid quarts, etc.

Conversion to metric system is costly, particularly where expensive and durable machinery is involved, and when the long range treatment of massive data requires conversion to the new unit. People must be retrained to some extent, and new tools and machinery purchased. However, conversion costs are a one time expense while the benefits continue. If the conversion is done over a long period of time, old tools and machinery can be replaced with metrically calibrated ones. Conversion in other countries has cost less than estimated.

Legislative Attempts to Convert the USA to the Metric System

In 1790, Thomas Jefferson proposed a system of measurement in the USA based on a decimal system using the inch and foot. A committee of the House submitted a report (1819) advising adoption of this plan but Congress took no action.

Another attempt to standardize a system of measurement for the United States occurred in 1821 when Secretary of State John Quincy Adams issued a "Report Upon Weights and Measures". One of the proposed courses of action in this report was adoption of the metric system. Again Congress took no action in response.

In 1863, a committee of the National Academy of Sciences led by Joseph Henry, reinvestigated the systems of weights, measures, and coinage being used and issued a report favorable to the adoption of the metric system. John Kasson, chairman of the House Committee on Coinage, Weights, and Measures reacted favorably to this report and eventually three metric bills were passed by Congress in 1866. The most important of these bills legalized the use of metric weights and measures in the United States.

An attempt to convert the nation to the metric system was made in 1896; however it was eventually defeated in Congress.

In 1968, Congress passed the Metric Study Bill authorizing the Secretary of Commerce "to conduct a program of investigation, research, and survey to determine the impact of increasing worldwide use of the metric system which may be feasible for the United States". This United States Metric Study was conducted by the National Bureau of Standards and completed in 1971. It recommended that the USA join the rest of the world in the use of the metric system. Legislation was drawn up which proposed the creation of a National Metric Conversion Board to advise industry, consumers, and legislators on how to adopt the metric system on a voluntary basis over a ten year period. This legislation declared that the costs of the metric conversion "should lie where they fall", meaning no federal aid would be paid for cost of tools made obsolete by the changeover or for retraining and other expenses of transition. Labor unions and small businesses opposed this plan because it provided no government reimbursement for retooling costs. This legislation was defeated. There are now nine metric bills pending the House of Representatives' subcommittee on Science, Research and Technology. Some of these bills do have provisions for financial assistance toward costs resulting from changeover to the metric system (15).

Some Conversions to the Metric System Which Have Already Occurred

Although there has been no national legislative committment to convert the United States to the metric system, a number of conversions have taken place. IBM, Caterpillar, Timken, International Harvester, Ford Motor, General Motors, Hewlett Packard, Honeywell and other industries have committed new products to metric design. The California Division of Oil and Gas was the first state agency in the USA to make the change. The first federal agency to change was the National Aeronautical and Space Administration on September 14, 1970. The Treasury Department has declared that domestic and imported wines must be bottled in seven standard metric sizes beginning on January 1, 1979.

The U.S. Army Reserve, U.S. Army Recruiting Command, and Army ROTC, are in the forefront of a campaign to introduce the metric system as quickly as possible in the nation's secondary schools. In cooperation with the National Bureau of Standards they are distributing to these schools valuable metric teaching aids including 600,000 wall charts and 12 million pocket size reference cards (12). The states of California, Maryland, and New Jersey are formally committed to teaching metrics in conjunction with the customary system in their school systems beginning in 1976. The New York State Education Department has also encouraged schools to hasten its introduction.

Metric units used for a large number of products such as films, pharmaceuticals, canned and packaged goods, skis, 7-Up, ball bearings, spark plugs, swimming pools, optometry supplies, dental and surgical instruments reflect the widespread use of the metric system in the United States. Road signs in metric units are being used in the states of Ohio and Minnesota and we have proposed such speed limit signs for use on the R.I.T. campus (8).

Although there are voluntary conversions to the metric system now being made, legislative action would provide for a more decisive and orderly change.

Acknowledgement

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Metric Information Office
U.S. Department of Commerce
National Bureau of Standards
Washington, D.C. 20234

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