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THE METRIC SYSTEM

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The metric system of measurement is now in mandatory legal use in countries in which almost 90 per cent of the total population of the world resides. It is legally authorized for use, although not yet mandatory, in the other countries of the world where foot-pound units, or the British system of measurement, still remain in official use. Canada is one of these few remaining "foot-pound countries," even though the use of metric measurement has been legal here since 1873; corresponding legal action was taken in the USA in 1866.

The fact that Great Britain, following a decision to adopt decimal coinage by 1971, has decided to convert completely to the metric system by 1975 is bound to have a profound effect upon Canada's position. When the time for the change to metric does come in this country, the Canadian construction industry will inevitably be involved. It is desirable, therefore, that the industry should have available in convenient form the essential facts about the metric system of measurement. It is the purpose of this Digest to provide such a summary statement.

It is not inappropriate that this should be the hundredth issue of the Canadian Building Digests, since the essence of the metric system is dependence upon multiples of ten for all its subdivisions. Although ten is, to some extent, a "natural" number it is not as convenient in some respects as the number twelve. It cannot be divided, for example, by three or four. But the natural advantages of the number ten, the fact that the whole number system is based upon ten and, above all, the almost universal use of the metric system throughout the world, exclusive of North America, combine to make it clearly desirable as the universal international system of measurement.

History

The basic idea of a decimal system of units is generally attributed to Simon Stevin (1548-1620) to whom the world is even more indebted for the concept of decimal fractions. In 1670, Gabriel Monton, Vicar of St. Paul's Church in Lyons, France, first proposed a comprehensive decimal system of measurement and suggested that this be based on the length of an arc of one minute of a great circle of the earth. The Academie des Sciences of France gave consideration to the use of decimal units from the time of its establishment in 1666.

It was, however, the intellectual ferment associated with the French Revolution that finally — and after a long interval — led to action. Advised by leading scientists of the day, Talleyrand, the great foreign minister of France at the turn into the nineteenth century, attempted to establish an international decimal system of weights and measures "à tous les temps, à tous les peuples." The proposal, first introduced in 1791, was based on the metre as a unit of length, defined as one ten-millionth part of the meridional quadrant of the earth. Checks upon this distance led to some of the earliest accurate geodetic survey work.

Acceptance of the new system in France, despite its distinguished scientific support, developed only very slowly. The Government of France was forced to pass a law as late as 1837 forbidding the use of the older system of measurement. Gradually, however, the metric system won approval not only in France but in a steadily increasing number of other countries.

In view of its recent adoption in Great Britain, it is of some interest to note that its use was permitted in the United Kingdom between 1864 and 1878. The British Weights and Measures (Metric System) Act of 1897 legalized its use in trade, but it was not until 1965 that the British Government, at the request of industry, announced the decision to convert all measurement to the metric system by 1975.

International Control

As the number of "metric countries" increased in the second half of the last century, the need for coordination of national systems of measurement became evident. The first basic international agreement regarding the metric system was the "Convention du Mètre." This treaty was signed by the plenipotentiaries of eighteen states in Paris in 1875. It was revised in 1921. Other states have joined in its support so that there are now over 40 adhering states. Any other state may join by simply notifying the French Government, with whom the treaty is deposited. The adherence is made final when the French Government informs the President of the International Committee (see below).

The Bureau International des Poids et Mesures was established under the terms of the original treaty. The Bureau provides the necessary technical and research supporting services to the international measurement system. Located in the Pavillon de Breteuil within the Parc de Saint-Cloud, about 10 kilometres southwest of the centre of Paris on land that has been deeded as international territory, the well-equipped laboratories of the Bureau now employ a staff of about 40, about two-thirds of whom are engaged on scientific work.

The work of the Bureau is under the general direction of the Comité International des Poids et Mesures (the International Committee on Weights and Measures). This important group consists of eighteen members from eighteen countries and is the key organization in the metric field. (Canada has played a notable role in this Committee, Dr. L. E. Howlett, Director of the Division of Applied Physics, NRC, having been elected President in 1964.)

Not only does this Committee nominate the Director and senior staff members of the Bureau, but it also has the privilege of calling the governments that adhere to the Convention du Mètre to meet in a Conférence Générale des Poids et Mesures. This Conference must be convened at least once every six years. It is the medium through which adhering governments agree on the exact details of the physical constants they will use, on the recommendation of the Committee. Seven Advisory Committees (Comités Consultatifs) composed of leading international authorities in metrology assist the main Committee with the detailed scientific aspects of its work.

Système International d'Unités (SI)

Six of these Advisory Committees deal respectively, with the scientific aspects of the definitions of the metre, the second, thermometry, electricity, photometry, and standards of ionizing radiations. The seventh Advisory Committee, established in 1964, is responsible for the coordination of the basic units in the International System of Units, more commonly known by the initials of the name in French. SI units are becoming well recognized as the desirable units for legal adoptions; and Britain's conversion is, officially, to SI units.

As early as 1913 the General Conference on Weights and Measures requested the International Committee to investigate the possibility of an integrated system of units. In the years following the Second World War an inquiry on the subject was addressed to all countries. Following discussion and study of the replies received by the International Committee, and following decisions of the General Conference in 1954 and 1960, the Système International was adopted. It is steadily coming into world-wide use not only on a national basis but also by such bodies as the International Organization for Standardization (ISO).

The Système International consists of six basic units and the coherent units derived from them. The basic units are for length (metre), mass (kilogram), time (second), electric current (ampere), absolute temperature (degree Kelvin), and luminous intensity (candela). A number of other important units — such as those for force and electrical resistance — can be derived from the basic units and are coherent with them. The Système is "coherent" in that the product or the quotient of any two unit quantities in the system is the unit of the resultant quantity. In other words, all derived units are directly interrelated with two or more of the six basic units.

The Système International also provides for uniformity in terminology and mathematical symbols. Typical items from the official list of fourteen multiples and sub-multiples of SI units are:

Multiplication	Factor	Prefix	Symbol
1,000	10^3	kilo	k
100	10^2	hecto	h
10	10^1	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m

The value of international agreement on such designations will be obvious.

Somewhat naturally, the scientific definitions for the basic units are, in general, very much more sophisticated than earlier metric descriptions. With the exception of the kilogram, all the basic units now depend fundamentally upon most accurate physical measurements such as can be carried out in a relatively few modern metrological laboratories. The kilogram, on the other hand, is still the weight of the polished cylinder of platinum-iridium alloy entrusted to the custody of the Bureau International des Poids et Mesures. It has a diameter of 39 mm, and its height is identical so that it roughly approximates a sphere.

SI Units

For convenient reference the current definitions of the six basic SI units are as follows, the numbers in parenthesis being the years in which the latest revisions of the definitions were approved:

Metre (m): The metre is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom (1960).

Kilogram (kg): The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram (1901).

Second (s): The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom (1967).

Ampere (A): The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton* per metre of length (1948).

Kelvin (°K): The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water (1967).

Candela (cd): The candela is the luminous intensity in the perpendicular direction of a surface of 1/600 000 square metre of a full radiator at the temperature of freezing platinum under a pressure of 101 325 newtons per square metre (1967).

These definitions will appear to some to be very rigorous and possibly far removed from the practice of everyday. It may be helpful, therefore, to note that Canada already uses three of the basic SI units — the second, the ampere, and the candela — and may soon be expected to use degree Celsius instead of degree Fahrenheit, which would be equivalent to using a fourth. There will then remain just the metre and the kilogram.

The Metric System

Although SI units will be those now universally adopted for legal official use, the "man in the street" may for some time think and talk of the more commonly appreciated metric units. But as the definitions of the standard foot and the standard pound are rarely thought about by those who use the British foot-pound system of measurement in everyday practice, so will SI units gradually come into use without consideration for the scientific definitions just cited. It is clearly desirable, however, that the scientific background of the more common SI units should be generally appreciated if only because it constitutes one of the reasons why the ultimate universal use of the Système International can be confidently predicted.

*Newton (N): SI unit for force, derived from the basic units and defined as that force which, applied to a mass of 1 kg, gives it an acceleration of 1m/sec/sec.

CONVERSION FACTORS

	Metric Unit	British Unit	Metric to British	British to Metric
Length	kilometre (km)		0.621 mile	
		mile		1.609 km
	metre (m)		3.281 ft	
		foot (ft)		0.305 m
	millimetre (mm)		0.0394 in	
		inch (in)		25.400 mm
Mass	kilogram (kg)		2.205 lb	
		pound (lb)		0.454 kg
	gram (g)		0.035 oz	
		ounce avoirdupois (oz)		28.350 g
Area	square kilometre (km^2)		0.386 $mile^2$	
		square mile ($mile^2$)		2.590 km
	hectare (ha)		2.471 acre	
		acre		0.405 ha
	square metre (m^2)		10.764 ft^2	
		square foot (ft^2)		0.093 m^2
	square millimetre (mm^2)		$1.550\ 00 \times 10^{-3}$ in^2	
		square inch (in^2)		645.16 mm^2
Volume	cubic metre (m^3)		35.315 ft^3	
		cubic foot (ft^3)		0.028 m^3
Capacity	litre (l)		0.220 gal	
		UK gallon (UKgal)		4.546 l
Force	newton (N)		0.225 lbf	
		pound-force (lbf)		4.448 N
Pressure, stress	newton per square metre (N/m^2)		1.4504×10^{-4} lbf/in^2	
		pound-force per square inch (lbf/in^2)		6894.8 N/m^2
Density (mass/volume)	kilogram per cubic metre (kg/m^3)		0.062 lb/ft^3	
		pound per cubic foot (lb/ft^3)		16.019 kg/m^3
	gram per cubic centimetre (g/cm^3)		0.036 lb/in^3	
		pound per cubic inch (lb/in^3)		27.680 g/cm^3

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