Reprinted from AUGUST, 1977 CEP

AIChE Goes Metric

Beginning in 1979, the International System of Units (SI) will be used in all Institute publications, meeting papers, and course texts.

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Schedules for AIChE entering into metric conversion using SI were determined by the AIChE Council at their March, 1977, meeting in Houston, Tex., based on recommendations from the Metrication Committee. The key point is that every paper submitted for presentation in an AIChE meeting, or submitted for publication in an AIChE journal, or any new course text submitted for presentation at an AIChE-sponsored course after January 1, 1979, must use SI units. Other units, such as Centimeter-Gram-Second (CGS) Metric, or English, may be used in addition, although this practice is discouraged.

On the accompanying pages is a guide to SI, including tables of conversion, which will be made available in quantity to all AIChE committees and divisions that need it.

SI is somewhat different than the CGS system, in use for many years, which has often been called the Metric System. SI is a system adopted internationally by the General Conference on Weights and Measures. Among some of the principles are the use of the kilogram for mass only, and the use of newton for force.

Pressure is expressed in terms of newtons per square meter, and is given the name, pascal. The pascal is a very small unit, and the kilopascal is suggested as the most common unit for pressure.

The main feature of SI is in the fact that it is coherent, which means that no conversion factors are needed when using basic or derived SI units. Any exception to the SI units destroys the coherency of the system, and is not really a step forward in usefulness.

The third column of Table 1 shows the metric units that may be used for an indefinite period of time with SI. These include the minute, hour, year, and liter. The fourth column contains units that are accepted for a limited period of time, probably on the order of five to 10 years, although this duration has not been established by the Institute. And finally, the fifth column lists those units that are definitely outside SI, and which will not be allowed in AIChE publications.

In the opinion of the Metrication Committee, there is no longer any question about eventual conversion to the metric system, and to SI in particular. The only question really is, when and how? AIChE is following the practice being instituted by many technical societies; we are not either leading or trailing significantly at present.

On the lighter side, the magnitude of the newton is about the weight of an apple. If we were to grind up that apple and spread it out over one square meter, we would have a pressure of one pascal, which may give a better feeling for the small size of that particular unit. Your Chairman of the Metrication Committee is approximately 2 meters tall, which was not a requirement, but can serve as a benchmark.

The Metrication Committee plans to submit a series of articles to *CEP* at two or three month intervals that will deal with various aspects of metric conversion. These are planned to include a typical process flow diagram in SI, a consideration of hard vs. soft conversion, consideration of conversion of various physical properties into SI, case histories of conversion in various industries and companies, and a description of the working of the International Standards Organizations.

Every AIChE committee and division has a member on the committee who acts as its liaison. Please feel free to call upon us for any assistance or information on conversion.

The Council resolution adopted National Bureau of Standards special publication 330, 1974 edition, entitled, "International System of Units (SI)." This is an official translation of the publication in French of the same title that was published by the International Bureau of Weights and Measures. In the last several months, there have been several American National Standards Institute publications on metric practices. The AIChE Committee is looking into adopting some of these or other publications, or preparing a separate, more detailed guide, if needed, on metric practice. In particular, the Institute of Electrical & Electronics Engineers' document, ANSI-Z210.1 - 1976 is accepted.

Table 1. Acceptable and unacceptable metric units.

		AIChE Recommendations		
Quantity	SI Unit	Accepted Alternate*	Temporary Alternate**	To Be Avoided†
Time	second	year day hour#		
Pressure	pascal		bar, atmosphere	kg force / cm²
Energy	joule	—	—	calorie kilowatt-hr.
Force	newton	—	—	dyne, kilogram
Mass	kilogram	metric ton	—	—
Volume	m^3	liter		
Viscosity	Pa . s	—	—	poise¶

*Table 8 NBS 330 **Table 10 NBS 330 †Tables 11 & 12 NBS 330

¶To be avoided because they were formerly used with the CGS system and are not part of SI.

#Not part of SI, but added by AIChE.

0001-1541-81-9351-0001-$2.00.

(REV., 1-1-78)

In addition, the American National Metric Council has published an editorial guide that contains much information for authors, editors, secretaries, and other people involved in publication. This is available through the American National Metric Council, 1625 Massachusetts Ave. N.W., Washington, D. C. 20036.

Note: *Reprints of this article and guide will be made available to AIChE groups at no charge for Institute business purposes. Individuals interested in copies for their personal use may obtain the reprints for $1.50 prepaid. In either case write: Publications Dept., AIChE, 345 E. 47 St., New York, N.Y., 10017.*

A Word About the Guide

This guide for the use of SI units, originally published in the May, 1971, issue of CEP, *has been updated and expanded slightly since then to conform to present practices. This material was prepared by Evan Buck, staff engineer, Union Carbide Corp., South Charleston, W. Va., a member of the Metrication Committee.*

Oldshue

Buck

Abbreviated Guide for Use of the SI

These tables summarize the SI unit system adopted by the AIChE Council on March 19, 1977, for use within the AIChE after January 1, 1979. This unit system is based on that documented in the National Bureau of Standards (NBS) Special Publication 330, 1974 edition, titled "The International System of Units (SI)," with the following modifications:

1. The "year" as a time unit has been added.
2. The symbol "L" rather than "l" is to be used as the abbreviation for liter, which avoids possible confusion with the numeral "1."
3. The prefixes "peta" (10^{15}) and "exa" (10^{18}) have been added.

Items 2 and 3 have been adopted by the NBS subsequent to the appearance of Publication 330.

SI Base Units

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

SI Supplementary Units

Quantity	SI unit Name	Symbol
plane angle	radian	rad
solid angle	steradian	sr

Examples of SI Derived Units Expressed in Terms of Base Units

Quantity	SI Unit Name	Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
kinematic viscosity	square meter per second	m^2/s
wave number	1 per meter	m^{-1}
density, mass density	kilogram per cubic meter	kg/m^3
current density	ampere per square meter	A/m^2
magnetic field strength	ampere per meter	A/m
concentration (of amount of substance)	mole per cubic meter	mol/m^3
activity (radioactive)	1 per second	s^{-1}
specific volume	cubic meter per kilogram	m^3/kg
luminance	candela per square meter	cd/m^2
angular velocity	radian per second	rad/s
angular acceleration	radian per second squared	rad/s^2

SI Derived Units With Special Names

Quantity	SI Unit Name	Symbol	Expression in terms of other units
frequency	hertz	Hz	s^{-1}
force	newton	N	$kg \cdot m/s^2$
pressure, stress	pascal	Pa	N/m^2
energy, work, quantity of heat	joule	J	$N \cdot m$
power, radiant flux	watt	W	J/s
quantity of electricity, electric charge	coulomb	C	$A \cdot s$
electric potential, voltage, potential difference, electromotive force	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
conductance	siemens	S	A/V
magnetic flux	weber	Wb	$V \cdot s$
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	$cd \cdot sr$
illuminance	lux	lx	$cd \cdot sr/m^2$

Examples of SI Derived Units Expressed by Means of Special Names

Quantity	SI Unit Name	SI Unit Symbol
dynamic viscosity	pascal-second	$Pa \cdot s$
moment of force	meter-newton	$N \cdot m$
surface tension	newton per meter	N/m
heat flux density, irradiance	watt per square meter	W/m^2
heat capacity, entropy	joule per kelvin	J/K
specific heat capacity, specific entropy	joule per kilogram-kelvin	$J/(kg \cdot K)$
specific energy	joule per kilogram	J/kg
thermal conductivity	watt per meter-kelvin	$W/(m \cdot K)$
energy density	joule per cubic meter	J/m^3
electric field strength	volt per meter	V/m
electric charge density	coulomb per cubic meter	C/m^3
electric flux density	coulomb per square meter	C/m^2
permittivity	farad per meter	F/m
permeability	henry per meter	H/m
molar energy	joule per mole	J/mol
molar entropy, molar heat capacity	joule per mole-kelvin	$J/(mol \cdot K)$
radiant intensity	watt per steradian	W/sr
radiance	watt per square meter-steradian	$W \cdot m^{-2} \cdot sr^{-1}$

Units in Use With the International System

Name	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3600 s
day	d	1 d = 24 h = 86400 s
year	yr	1 yr ≈ 365 d
degree	°	1° = (π/180) rad
minute	′	1′ = (1/60)° = (π/10800) rad
second	″	1″ = (1/60)′ = (π/648000) rad
liter	L	1 L = 1 dm^3 = 10^{-3} m^3
metric ton	t	1 t = 10^3 kg
nautical mile		1 nautical mile = 1852 m
knot		1 nautical mile per hour = (1852/3600) m/s
ångström	Å	1 Å = 0.1 nm = 10^{-10} m
are	a	1 a = 1 dam^2 = 10^2 m^2
hectare	ha	1 ha = 1 hm^2 = 10^4 m^2
barn	b	1 b = 100 fm^2 = 10^{-28} m^2
bar	bar	1 bar = 0.1 MPa = 10^5 Pa
standard atmosphere	atm	1 atm = 101325 Pa
gal	Gal	1 Gal = 1 cm/s^2 = 10^{-2} m/s^2
curie	Ci	1 Ci = 3.7 × 10^{10} s^{-1}
röntgen	R	1 R = 2.58 × 10^{-4} C/kg
rad	rad	1 rad = 10^{-2} J/kg

Note: *In addition to the thermodynamic temperature (symbol T), expressed in kelvins, use is also made of Celsius temperature (symbol t) defined by the equation*

$$t = T - T_0$$

where T_0 = 273.15 K by definition. The Celsius temperature is expressed in degrees Celsius (symbol °C). The unit "degree Celsius" is thus equal to the unit "kelvin," and an interval or a difference of Celsius temperature may also be expressed in degrees Celsius.

SI Prefixes

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

Directions for Use

SI symbols are not capitalized unless the unit is derived from a proper name; e.g., Hz for H. R. Hertz. Unabbreviated units are not capitalized; e.g., hertz, newton, kelvin. Only E, P, T, G, *and* M *prefixes are capitalized.*

Except at the end of a sentence, SI units are not to be followed by periods.

In derived unit symbols, use center dot to denote multiplication and a slash for division; e.g., newton-second per square meter = N·s / m^2.

Conversion Factors to SI for Selected Quantities

*An asterisk after the seventh decimal place indicates the conversion factor is exact and all subsequent digits are zero.

To convert from	To	Multiply by
barrel (for petroleum, 42 gal)	$meter^3$ (m^3)	1.5898729 E − 01
British thermal unit (Btu, International Table)	joule (J)	1.0550559 E + 03

Continued

To convert from	To	Multiply by
Btu/lbm-deg F (heat capacity)	joule/kilogram-kelvin (J/kg·K)	4.1868000* E + 03
Btu/hour	watt (W)	2.9307107 E − 01
Btu/second	watt (W)	1.0550559 E + 03
Btu/ft^2-hr-deg F (heat transfer coefficient)	joule/meter^2-second-kelvin (J/m^2·s·K)	5.6782633 E + 00
Btu/ft^2-hour (heat flux)	joule/meter^2-second (J/m^2·s)	3.1545907 E + 00
Btu/ft-hr-deg F (thermal conductivity)	joule/meter-second-kelvin (J/m·s·K)	1.7307347 E + 00
calorie (International Table)	joule (J)	4.1868000* E + 00
calorie (Thermochemical)	joule (J)	4.1840000* E + 00
cal/g·deg C	joule/kilogram-kelvin (J/kg·K)	4.1868000* E + 03
centimeter	meter (m)	1.0000000* E − 02
centimeter of mercury (0°C)	pascal (Pa)	1.3332237 E + 03
centimeter of water (4°C)	pascal (Pa)	9.80638 E + 01
centipoise	pascal-second (Pa·s)	1.0000000* E − 03
centistokes	meter^2/second (m^2/s)	1.0000000* E − 06
degree Fahrenheit (°F)	kelvin (K)	$t_K = (t_F + 459.67)/1.8$
degree Rankine (°R)	kelvin (K)	$t_K = t_R/1.8$
dyne	newton (N)	1.0000000* E − 05
erg	joule (J)	1.0000000* E − 07
farad (International of 1948)	farad (F)	9.99505 E − 01
fluid ounce (U.S.)	meter^3 (m^3)	2.9573530 E − 05
foot	meter (m)	3.0480000* E − 01
foot (U.S. Survey)	meter (m)	3.0480061 E − 01
foot of water (39.2°F)	pascal (Pa)	2.98898 E + 03
foot^2	meter^2 (m^2)	9.2903040* E − 02
foot/second^2	meter/second^2 (m/s^2)	3.0480000* E − 01
foot^2/hour	meter^2/second (m^2/s)	2.5806400* E − 05
foot-pound-force	joule (J)	1.3558179 E + 00
foot^2/second	meter^2/second (m^2/s)	9.2903040* E − 02
foot^3	meter^3 (m^3)	2.8316847 E − 02
gallon (U.S. liquid)	meter^3 (m^3)	3.7854118 E − 03
gram	kilogram (kg)	1.0000000* E − 03
horsepower (550 ft-lbf/s)	watt (W)	7.4569987 E + 02
inch	meter (m)	2.5400000* E − 02
inch of mercury (60°F)	pascal (Pa)	3.37685 E + 03
inch of water (60°F)	pascal (Pa)	2.48843 E + 02
inch^2	meter^2 (m^2)	6.4516000* E − 04
inch^3	meter^3 (m^3)	1.6387064* E − 05
kilocalorie	joule (J)	4.1868000* E + 03
kilogram-force (kgf)	newton (N)	9.8066500* E + 00
micron	meter (m)	1.0000000* E − 06
mil	meter (m)	2.5400000* E − 05
mile (U.S. Statute)	meter (m)	1.6093440* E + 03
mile/hour	meter/second (m/s)	4.4704000* E − 01
millimeter of mercury (0°C)	pascal (Pa)	1.3332237 E + 02
ohm (International of 1948)	ohm (Ω)	1.000495 E + 00
ounce-mass (avoirdupois)	kilogram (kg)	2.8349523 E − 02
ounce (U.S. fluid)	meter^3 (m^3)	2.9573530 E − 05
pint (U.S. liquid)	meter^3 (m^3)	4.7317647 E − 04
poise (absolute viscosity)	pascal-second (Pa·s)	1.0000000* E − 01
poundal	newton (N)	1.3825495 E − 01
pound-force (lbf)	newton (N)	4.4482216 E + 00
pound-force-second/ft^2	pascal-second (Pa·s)	4.7880258 E + 01
pound-mass (lbm avoirdupois)	kilogram (kg)	4.5359237* E − 01
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.6018463 E + 01
pound-mass/foot-second	pascal-second (Pa·s)	1.4881639 E + 00
psi	pascal (Pa)	6.8947573 E + 03
quart (U.S. liquid)	meter^3 (m^3)	9.4635295 E − 04
slug	kilogram (kg)	1.4593903 E + 01
stokes (kinematic viscosity)	meter^2/second (m^2/s)	1.0000000* E − 04
ton (long, 2240 lbm)	kilogram (kg)	1.0160469 E + 03
ton (short, 2000 lbm)	kilogram (kg)	9.0718474* E + 02
torr (mm Hg, 0°C)	pascal (Pa)	1.3332237 E + 02
volt (International of 1948)	volt (absolute) (V)	1.000330 E + 00
watt (International of 1948)	watt (W)	1.000165 E + 00
watt-hour	joule (J)	3.6000000* E + 03
yard	meter (m)	9.1440000* E − 01