AICHE GOES METRIC

Beginning in 1979, the International System of the 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 in 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 often called the Metric System, which has been in use for many years. SI is a system adopted internationally by the General Conference of Weights and Measures. Among some of the principles are the use of the kilogram for mass only, and the use of newton for force or weight.

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 coherence 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 definite outside SI, and which will not be allowed in AIChE publications.

* Reference: Chemical Engineering Progress, August 1977, Vol. 73, No. 8, pp. 135-138.

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 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 information on conversion.

The Council resolution adopted National Bureau of Standards special publication 330, 1974 edition, entitled, "International System of Units (SI)." This is a translation of the proceedings of the last General Conference of Weights and Measures, which set up the present rules of SI. 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 and Electronics Engineers' document, ANSI-210.1-19xx is accepted.

In addition, the American Metric Council has published an editorial guide that contains 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.

TABLE 1. Acceptable and unacceptable metric units.

Quantity	*SI Unit*	*AIChE Recommendations*		
		Accepted Alternate	*Temporary Alternate*	*Avoided To Be*
Time	second	year day hour		
Pressure	pascal		bar, atmosphere	*kg force* / m^2
Energy	joule			calorie kilowatt-hr.
Force	newton			dyne,, kilogram
Mass	kilogram	ton		
Volume	m^3	liter		
Viscosity				poise

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 usd 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·m
power, radiant flux	watt	W	J/s
quantity of electricity, eletricity charge	coulomb	C	A·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·s
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	cd·sr
illuminance	lux	lx	$cd \cdot sr/m^2$

Examples of SI Derived Units

Expressed by Means of

Special Names

Quantity	*SI Unit*	
	Name	*Symbol*
dynamic viscosity	pascal-second	Pa·s
moment of force	meter-newton	N·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·K)
specific energy	joule per kilogram	J/kg
thermal conductivity	watt per meter-kelvin	W/(m·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·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 = $10^{-3}m^3$
ton	t	1 t = 10^3 kg
nautical mile		1 nautical mile = 1852 m
knot		1 nautical mile per hour = (1852/3600)m/s
angstrom	A°	1 A° = 0.1 nm = 10^{-10}m
are	a	1 a = 1 dam^2 = 10^2m^2
hectare	ha	1 ha = 1 hm^2 = 10^4m^2
barn	b	1 b = 100 fm^2 = $10^{-28}m^2$
bar	bar	1 bar = 0.1 MPa = 10^5Pa
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
rontgen	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	u
10^{6}	mega	M	10^{-9}	nano	
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 paper 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. With derived unit abbreviations, use center dot to denote multiplication and a slash for division; e.g., newton-second/meter^2 = N·s/^{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
Btu/1 bm-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

To convert from	*To*	*Multiply by*
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
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
centistoke	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	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

To convert from	*To*	*Multiply by*
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 (1bf avoirdupois)	newton (N)	4.4482216 E + 00
pound-force-second/ft^2	pascal-second (Pa·s)	4.7880258 E + 01
pound-mass (1bm 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
stoke (kinematic viscosity)	meter^2/second (m^2/s)	1.0000000* E − 04
ton (long, 2240 1bm)	kilogram (kg)	1.0160469 E + 03
ton (short, 2000 1bm)	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