INTERNATIONAL SYSTEM OF UNITS

INTRODUCTION

The U.S. is one of the last countries still officially using the “English” measurement system. Most other countries use metric (decimal) systems. However, not all metric systems use the same units. For consistency, the 11th General Conference on Weights and Measures established the International System of Units (SI). This system has been adopted by the International Organization for Standardization (ISO), ASTM International (ASTM) and other organizations. The system is outlined in detail in “Specification for Quantities, Units and Symbols” (ISO 31) and in “Standard for Metric Practice” (ASTM E380).

This PRC Guideline describes the SI units and gives common conversion factors. All PRC Guidelines and Association publications contain SI units (or other units accepted by the SI standard). In most cases, the SI units are in parentheses following the more commonly used English unit. When a quoted source uses SI units, the SI units are shown first with the English units following in parentheses. Table 5 shows the units commonly used in fire protection systems. The SI units to be used in AXA XL Risk Consulting’s publications and correspondence are marked with “**.”

In most cases, the SI equivalent need not be more than three significant figures. It should rarely be more than the number of significant figures of the “English unit.” For example, if an AXA XL Risk Consulting recommendation calls for a 75 ft separation between buildings it is proper to use an SI equivalent of 23 m. Using 22.9 m is misleading because the distance in ft is accurate only to two significant figures.

POSITION

Use the SI units defined in this PRC Guideline. SI is based on the seven well-defined units listed in Table 1. Based on these seven units, a number of standard derived units have been adopted and have been given special names and symbols. Table 2 shows a partial list of derived units. Table 3 shows other units allowed by the SI standard.

TABLE 1
Basic SI Units

Quantity	Units	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

TABLE 2
Derived SI Units

Quantity	Units	Symbol	Formula
Frequency	Hertz	Hz	1/s
Force	Newton	N	$kg \cdot m/s^2$
Pressure, stress	Pascal	Pa	N/m^2
Energy, work, heat	Joule	J	$N \cdot m$
Power, radiant flux	Watt	W	J/s
Quantity of electricity	Coulomb	C	$A \cdot s$
Electric potential	Volt	V	W/A
Capacitance	Farad	F	C/V
Electric resistance	Ohm	Ω	V/A
Acceleration	Meter per second squared		m/s^2
Area	Square meter		m^2
Concentration (of amount of substance)	mole per cubic meter		mol/m^3
Density, mass	kilogram per cubic meter		kg/m^3
Heat capacity	joule per kelvin		J/K
Heat flux density irradiance	watt per square meter		W/m^2
Specific heat capacity	joule per kilogram kelvin		$J/(kg \cdot K)$
Specific energy	joule per kilogram		J/kg
Specific volume	cubic meter per kilogram		m^3/kg
Velocity	meter per second		m/s
Volume	cubic meter		m^3

TABLE 3
Allowed SI Units

Quantity	Unit	Symbol	Definition
Time	Minute	min	1 min = 60s
	Hour	h	1h = 60 min = 3600s
	Day	d	1d = 24h = 86400s
	week, month, etc.	---	---
Temperature	degree Celsius	°C	°C = °K - 273.15
Volume	liter	L	$1L = 1dm^3 = 10^{-3}m^3$
Mass	metric ton (tonne)	t	$1t = 10^3kg$
Pressure (limited use only)	bar	bar	$1 bar = 10^5Pa$

TABLE 4
SI Unit Prefix Relationships

Multiplication Factor	Prefix	Symbol
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

MULTIPLICATION FACTORS

Prefixes to basic and derived SI units indicate the multiplication factor to be applied to the units. Using these prefixes makes the number a workable size by eliminating nonsignificant digits and leading zeros in decimal fractions.

For example, 12,300 meters (m) = 12.3 $\times$ 103m = 12.3 km. Table 4 shows the prefix relationships.

Only one prefix should be used with each unit. For example, one thousand (1000) kilograms should not be expressed as 1 kkg but as 1000 kg or 1 Mg.

CONVERSION FACTORS

Tables 5 and 6 give factors to convert common English and nonstandard metric units to SI units. The multiplier is expressed as a whole number and an exponential. For example:

1.198 264 E+02 = 1.198 264 $\times$ 10^{2}= 119.8264

9.144 000 E-01 = 9.144 000 $\times$ 10^{-1}= 0.9144000

An asterisk (*) after the sixth decimal place indicates that the conversion factor is exact and that all subsequent digits are zero.

TABLE 5
Common Fire Protection Units

To convert from	To	Multiply by
gal (U.S.)	liter (L)**	3.785 412 E+00
	meter^3 (m^3)	3.785 412 E-03
gal/min (U.S. gpm)	liter per minute (L/min)**	3.785 412 E+00
	meter^3 per minute (m^3/min)	3.785 412 E-03
	liter per second (L/sec)	6.309 020 E-02
	meter^3 per second (m^3/sec)	6.309 020 E-05
ft^3/min (cfm)	meter^3 per minute (m^3/min)**	2.831 685 E-02
	meter^3 per second (m^3/sec)	4.719 474 E-04
U.S. gal/min/ft^2 (Sprinkler density)	liter per minute per meter^2 (L/min/m^2)**	4.074 584 E+01
	millimeter per minute (mm/min)	4.074 584 E+01
inch***	millimeter (mm)**	2.540 000*E+01
foot	meter (m)**	3.048 000*E-01
foot^2	meter^2 (m^2)**	9.290 304*E-02
pound	kilogram (kg)**	4.535 924 E-01
psi	bar**	6.894 757 E-02
	kilopascal (kPa)	6.894 757 E+00
degree F	degree C**	°C=(°F-32)/1.8

** SI Units used in AXA XL Risk Consulting publications and correspondence.

*** Conversions of pipe size and sprinkler orifice size use nominal sizes as shown in the Tables 7 & 8.

TABLE 6
Other Common Conversion Factors

To convert from	To	Multiply by
Acceleration		
ft/s^2	meter per second^2 (m/s^2)	3.048 000*E-01
in./s^2	meter per second^2 (m/s^2)	2.540 000*E-02
Area		
Acre (U.S. survey)	meter^2 (m^2)	4.046 873 E+03
ft^2	meter^2 (m^2)	9.290 304*E-02
in.^{2}	meter^2 (m^2)	6.451 600*E-04
mi^2 (international)	meter^2 (m^2)	2.589 988 F+06
yd^2	meter^2 (m^2)	8.361 274 E-01
Capacity (See Volume)		
Density (See Mass per Unit Volume)		
Energy (Includes Work)		
British thermal unit (thermochemical)	joule (J)	1.054 350 E+03
calorie (thermochemical)	joule (J)	4.184 000*E+00
ft • lbf	joule (J)	1.355 818 E+00
kilocalorie (thermochemical)	joule (J)	4.184 000*E+03
kW • h	joule (J)	3.600 000*E+06
k • hp	joule (J)	3.600 000*E+03
W • s	joule (J)	1.000 000*E+00
Energy per Unit Area per Unit Time		
Btu (Thermochemical)/ft^2 • s	watt per meter^2 (W/m^2)	1.134 893 E+04
Btu (Thermochemical)/ft^2 • m	watt per meter^2 (W/m^2)	1.891 489 E+02
Btu (Thermochemical)/ft^2 • h	watt per meter^2 (W/m^2)	3.152 481 E+00
Flow (See Mass per Unit Time or Volume per Unit Time)		
Force		
dyne	newton (N)	1.000 000*E-05
kilogram-force	newton (N)	9.806 650*E+00
pound-force (lbf)	newton (N)	4.448 222 E+00
Force per Unit Area (See Pressure)		

TABLE 6 (Cont'd.)
Other Common Conversion Factors

To convert from	To	Multiply by
Force per Unit Length		
1bf/ft	newton per meter (N/m)	1.459 390 E+01
1bf/in.	newton per meter (N/m)	1.751 268 E+02
Heat Content		
Btu (thermochemical)/ft^2	joule per meter^2 (J/m^2)	1.134 893 E+04
Btu (thermochemical)/h ft^2 • °F	watt per meter^2 kelvin (W/m^2 • K)	5.674 466 E+00
Btu (thermochemical)/lb	joule per kilogram (J/kg)	2.324 444 E+03
Btu (thermochemical)/lb°F	joule per kilogram kelvin (J/kg • K)	4.184 000 E+03
cal (thermochemical)/cm^2	joule per meter^2 (J/m^2)	4.184 000*E+04
cal (thermochemical)/g	joule per kilogram (J/kg)	4.184 000*E+03
cal (thermochemical)/g • °C	joule per kilogram kelvin (J/kg • K)	4.184 000*E+03
Length		
foot	meter (m)	3.048 000*E-01
inch	meter (m)	2.540 000*E-02
mile (statute)	meter (m)	1.609 300 E+03
yard	meter (m)	9.144 000*E-01
Mass		
gram	kilogram (kg)	1.000 000*E-03
ounce (avoirdupois)	kilogram (kg)	2.834 952 E-02
pound (1 lb avoirdupois)	kilogram (kg)	4.535 924 E-01
ton (short, 2000 lb)	kilogram (kg)	9.071 847 E+02
tonne	kilogram (kg)	1.000 000*E+03
Mass Per Unit Capacity (See Mass per Unit Volume)		
Mass per Unit Time (Includes Flow)		
lb/h	kilogram per second (kg/s)	1.259 979 E-04
lb/min	kilogram per second (kg/s)	7.559 873 E-03
lb/s	kilogram per second (kg/s)	4.535 924 E-01
Mass per Unit Volume (Includes Density and Mass Capacity)		
g/cm^3	kilogram per meter^3 (kg/m^3)	1.000 000*E+03
lb/ft^3	kilogram per meter^3 (kg/m^3)	1.601 846 E+01
lb/in.^{3}	kilogram per meter^3 (kg/m^3)	2.767 990 E+04
lb/gal (U.S. liquid)	kilogram per meter^3 (kg/m^3)	1.198 264 E+02
Power		
Btu (thermochemical)/h	watt (W)	2.928 751 E-01
Btu (thermochemical)/min	watt (W)	1.757 250 E+01
Btu (thermochemical)/s	watt (W)	1.054 350 E+03
cal (thermochemical)/min	watt (W)	6.973 333 E-02
cal (thermochemical)/s	watt (W)	4.184 000*E+00
horsepower (boiler)	watt (W)	9.809 50 E+03
horsepower (electric)	watt (W)	7.460 000*E+02
horsepower (metric)	watt (W)	7.354 99 E+02
horsepower (water)	watt (W)	7.460 43 E+02
kilocalorie (thermochemical)/min	watt (W)	6.973 333 E+01
kilocalorie (thermochemical)/s	watt (W)	4.184 000*E+03
ton (refrigeration)	watt (W)	3.516 800 E+03
Pressure or Stress (Force per Unit Area)		
atmosphere (standard)	pascal (Pa)	1.013 250*E+05
bar	pascal (Pa)	1.000 000*E+05
centimeter of mercury (0°C)	pascal (Pa)	1.333 22 E+03
foot of water (39.2°F)	pascal (Pa)	2.988 98 E+03
inch of mercury (32°F)	pascal (Pa)	3.386 38 E+03

TABLE 6 (Cont'd.)
Other Common Conversion Factors

To convert from	To	Multiply by
inch of mercury (60°F)	pascal (Pa)	3.376 85 E+03
inch of water (39.2°F)	pascal (Pa)	2.490 82 E+02
inch of water (60°F)	pascal (Pa)	2.488 4 E+02
kgf/cm^2	pascal (Pa)	9.806 650*E+04
kgf/m^2	pascal (Pa)	9.806 650*E+00
kgf/mm^2	pascal (Pa)	9.806 650*E+06
millibar	pascal (Pa)	1.000 000*E+02
millimeter of mercury (0°C)	pascal (Pa)	1.333 22 E+02
lbf/ft^2	pascal (Pa)	4.788 026 E+01
lbf/in.^{2} (psi)	pascal (Pa)	6.894 757 E+03
psi	pascal (Pa)	6.894 757 E+03
Speed (See Velocity)		
Temperature		
degree Celsius	kelvin (K)	K = °C+273.15
degree Fahrenheit	degree Celsius	°C=(°F-32)/1.8
degree Fahrenheit	kelvin (K)	K=(°F+459.67)/1.8
degree Rankine	kelvin (K)	K=°R/1.8
kelvin	degree Celsius	°C=K - 273.15
Velocity (Includes Speed)		
ft/h	meter per second (m/s)	8.466 667 E-05
ft/min	meter per second (m/s)	5.080 000*E-03
ft/s	meter per second (m/s)	3.048 000*E-01
in./s	meter per second (m/s)	2.540 000*E-02
knot (international)	meter per second (m/s)	5.144 444 E-01
mi/h (international)	meter per second (m/s)	4.470 400*E-01
mi/min (international)	meter per second (m/s)	2.682 240*E+01
mi/h (international)	kilometre per hour (km/h)**	1.609 344*E+00
**Although speedometers may read km/h, the standard SI unit is m/s.		
Viscosity		
centipoise	pascal second (Pa • s)	1.000 000*E-03
centistokes	meter^2 per second (m^2/s)	1.000 000*E-06
poise	pascal second (Pa • s)	1.000 000*E-01
stokes	meter^2 per second (m^2/s)	1.000 000*E-04
Volume (Includes Capacity)		
barrel (oil, 42 gal)	meter^3 (m^3)	1.589 873 E-01
bushel (U.S.)	meter^3 (m^3)	3.523 907 E-02
cup	meter^3 (m^3)	2.365 882 E-04
fluid ounce (U.S.)	meter^3 (m^3)	2.957 353 E-05
ft^3	meter^3 (m^3)	2.831 685 E-02
gallon (U. S. liquid)	meter^3 (m^3)	3.785 412 E-03
in.^{3}	meter^3 (m^3)	1.638 706 E-05
liter	meter^3 (m^3)	1.000 000*E-03
ounce (U.S. fluid)	meter^3 (m^3)	2.957 353 E-05
pint (U.S. liquid)	meter^3 (m^3)	4.731 765 E-04
quart (U.S. liquid)	meter^3 (m^3)	9.463 529 E-04
yd^3	meter^3 (m^3)	7.645 549 E-01
Volume per Unit Time (Includes Flow)		
ft^3/min	meter^3 per second (m^3/s)	4.719 474 E-04
ft^3/s	meter^3 per second (m^3/s)	2.831 685 E-02
in.^{3}/min	meter^3 per second (m^3/s)	2.731 177 E-07
gal (U.S.liquid)/d	meter^3 per second (m^3/s)	4.381 264 E-08
gal (U.S.liquid)/min	meter^3 per second (m^3/s)	6.309 020 E-05
Work (See Energy)		

TABLE 7
Piping Equivalents

¼ in. = 6 mm	1¾ in. = 45 mm	8 in. = 200 mm
⅜ in. = 10 mm	2 in. = 50 mm	10 in. = 250 mm
½ in. = 15 mm	2½ in. = 65 mm	12 in. = 300 mm
¾ in. = 20 mm	3 in. = 80 mm	14 in. = 350 mm
1 in. = 25 mm	3½ in. = 90 mm	16 in. = 400 mm
1¼ in. = 32 mm	4 in. = 100 mm	18 in. = 450 mm
1½ in. = 40 mm	5 in. = 125 mm	20 in. = 500 mm
	6 in. = 150 mm	24 in. = 600 mm

PIPING

Nominal pipe sizes have nominal metric equivalents. Direct conversion from in. to mm relating to pipe size is meaningless. Therefore, use Table 7 for specifying pipe sizes. The equivalents in Table 7 should be used only for pipe size conversions.

SPRINKLERS

Sprinkler Orifice Sizes

Most sprinkler codes outside the U.S. list only three standard sprinkler sizes. These are the ⅜ in., ½ in., and 17⁄32 in. orifices with the nominal sizes listed in Table 8. The term “nominal orifice” can be misleading because in most cases thread size is meant. An exception would be a 20 mm (17⁄32 in.) sprinkler with 15 mm (½ in.) threads. NFPA 13 allows the use of these sprinklers only when retrofitting existing sprinkler installations. Therefore, there should be a limited need to recommend them.

TABLE 8
Sprinkler Orifice Equivalents

⅜ in. nominal orifice	= 10 mm nominal orifice
½ in. nominal orifice	= 15 mm nominal orifice
17⁄32 in. nominal orifice	= 20 mm nominal orifice

Because so many different sprinkler orifice sizes are now available, the nominal SI equivalents do not distinguish between them. It has become customary to refer to sprinklers by their K-factor rather than their orifice size. NFPA 13 identifies sprinklers by K-factor.

Always refer to large drop sprinklers as large drop sprinklers rather than using an orifice size or K-factor, because these heads have water distribution characteristics different from other heads with the same size orifice. Similarly, refer to ESFR heads as ESFR heads along with their K-factor, e.g., K-14 ESFR or K-25 ESFR.

K-Factors

Sprinkler K-factors are used in the equation $Q = K\sqrt{p}$, where *Q* is in gal/min (L/min) and *p* is in psi (bars). Although units are not usually stated with the K-factor, these units are $\frac{\text{gpm}}{\sqrt{\text{psi}}}$ ($\frac{\text{L/m}}{\sqrt{\text{bars}}}$). The English and metric K factors can be converted the using the formula $K_m = 14K_e$.

Sprinkler Sensitivity

RTI is a measure of sprinkler sensitivity. As in the case with the K-factor, the units are not usually stated. They are $ft^{½}$ $sec^{½}$ ($m^{½}$ $sec^{½}$). English and metric RTI values can be converted using the formula $RTI_e = 1.78\ RTI_m$. However, since small differences in RTI values are not significant, most sprinkler manufacturers do not publish specific RTI values for their sprinklers. AXA XL Risk Consulting does not recommend specific RTI values, but only whether the sprinkler should be standard or quick response.

CONTAINER SIZE

In the U.S. the most common size liquids drum is 55 gal. This converts to 208 L; however, countries using metric units refer to them as 200 L drums.

TEMPERATURE DIFFERENCES

Converting between English and SI units normally involves only multiplicative factors. In that case, converting differences between units involves the same factor. For example, to convert feet to meters multiply by 0.305. To convert a difference in feet (such as difference between heights of two exposing buildings) to a difference in meters, also multiply by 0.305.

Converting between English and metric temperatures involves both multiplicative and additive factors. Converting temperature differences (such as the number of degrees above ambient temperature) is not same as converting temperatures. For example, to convert 20°F to °C, use the formula (°F-32)/1.8. To convert a temperature difference of 20°F to °C, divide by 1.8. This is because a Fahrenheit degree is 1.8 times smaller than a Celsius degree.

Fahrenheit and Rankine degrees are the same size. Celsius degrees and kelvins are the same size.

NOMINAL DIMENSIONS

For convenience, many products are specified by means of their nominal dimensions. These dimensions may be in English units, SI units, or neither. Do not indiscriminately convert such nominal dimensions to other units.

Common examples of nominal dimensions include sprinkler piping and orifice sizes, the conversions for which are given in Tables 7 and 8. Another common example is the designation “2 by 4” lumber, which should not be converted to SI units.

Inch-based trade sizes of nuts and bolts precisely designate a critical dimension of the product. Do not convert these sizes to SI units. It is acceptable to use nominal metric designations if they have been adopted by trade associations or standards organizations.

Do not convert sheet metal and wire gauges. These gauges are inherently neither English nor metric, but are specified for each type of product by the manufacturer. If referring to a particular product, it is acceptable to use the nominal English and metric dimensions provided by the manufacturer.

Engineering handbooks give more information on some nominal dimensions.