Kirk-Othmer Encyclopedia of Chemical Technology.

UNITS AND CONVERSION FACTORS

The barleycorn, inch, foot, yard, rod, furlong, mile, league, ell, fathom, and chain are units of length that the North American colonies inherited from the British. The inch was originally the length of three barleycorns; the yard was the distance from the tip of the nose to the tip of the middle finger on the outstretched arm of a British king (Henry I); the acre was the amount of land plowed by a yoke of oxen in a day. This system of units is very old and may be traced back to ancient Egypt.

A jumble of units existed throughout the world even until the late eighteenth century. In 1790, the French National Assembly requested of the French Academy of Sciences that it work out a system of units suitable for adoption by the whole world. This system was based on the meter as a unit of length and the gram as a unit of mass. Industry, commerce, and especially the scientific community benefited greatly. In 1893, the United States actually adopted the meter and the kilogram as the fundamental standards of length and mass. Although the spellings metre and litre are preferred by the author and ASTM, meter and liter are used in the *Encyclopedia.*

The foundation to international standardization of units was laid with an international treaty, the Meter Convention, which was signed by 17 countries, including the United States, in 1875. This treaty established a permanent International Bureau of Weights and Measures and defined the meter and the kilogram, from which evolved a set of units for the measurement of length, area, volume, capacity, and mass. Also established was the General Conference on Weights and Measures (CGPM), which was to meet at regular intervals to consider any needed improvements in the standards. The National Institute of Standards and Technology (NIST) represents the United States in these activities.

From these early beginnings, several variants of the metric system evolved. With the addition of the second as a unit of time, the centimeter–gram–second (cgs) system was adopted in 1881. In the early 1900s, practical measurements in metric units began to be based on the meter–kilogram–second (mks) system. In 1935, the International Electrotechnical Commission adopted a proposal to link the mks system of mechanics with the electromagnetic system of units by adding the ampere as a base unit and forming the mksA (meter–kilogram–second–ampere) system.

In 1954, the 10th CGPM added the degree Kelvin as the unit of temperature and the candela as the unit of luminous intensity. At the time of the 11th CGPM in 1960, this new system with six base units was formalized with the title International System of Units. Its abbreviation in all languages is SI, from the French *Le Système International d'Unités.*

Since 1960, various refinements to the system have been made, including redefinition of the second based on the atomic frequency of cesium; change of the name of the unit of temperature from degree Kelvin to the kelvin (symbol K); redefinition of the candela (all in 1967); addition of a seventh base unit, the mole (mol), as the unit of amount of substance; the pascal (Pa) as a special name for the SI unit of pressure or stress, equal to a newton per square meter; the siemens (S) as a special name for the unit of electric conductance, equal to the ampere per volt (all in 1971); addition of two SI units for ionizing radiation, the becquerel (Bq) as the unit of activity, equal to one reciprocal second, and the gray (Gy) as the unit of absorbed dose, equal to one joule per kilogram; prefixes for 10^{18}, exa (E), and 10^{15}, peta (P) (all in 1975); addition of the sievert (Sv) as the unit of dose equivalent, equal to one joule per kilogram; further redefinition of the candela; recognition of both l and L as symbols for liter (all in 1979); and interpretation of the radian and the steradian as dimensionless derived units for which the CGPM allows the freedom of use or nonuse in expressions for SI-derived units (1980).

In order to increase the precision of realization of the base unit meter, the definition based on the wavelength of a krypton-86 radiation was replaced in 1983 by one based on the speed of light. Also added were the prefixes zetta (Z) for 10^{21}, zepto (z) for 10^{-21}, yotta (Y) for 10^{24}, and yocto (y) for 10^{-24}.

In 1995 the 20th CGPM approved eliminating the class of supplementary units as a separate class in SI. Thus the new SI consists of only two classes of units: base units and derived units, with the radian and steradian subsumed into the class of derived units of the SI.

1. Advantages of SI

SI is a decimal system. Fractions have been eliminated, and multiples and submultiples are formed by a system of prefixes ranging from yotta, for 10^{24}, to yocto, for 10^{-24}. Calculations, therefore, are greatly simplified.

Each physical quantity is expressed in one and only one unit, eg, the meter for length, the kilogram for mass, and the second for time. Derived units are defined by simple equations relating two or more base units. Some are given special names, such as newton for force and joule for work and energy.

In an energy-conscious world, SI provides a direct relationship among mechanical, electric, chemical, thermodynamic, molecular, and solar forms of energy. All power ratings are given in watts.

The system is coherent. There is no duplication of units for a quantity, and all derived units are obtained by a direct one-to-one relation of base units or derived units; eg, one newton is the force required to accelerate one kilogram at the rate of one meter per second squared; one joule is the energy involved when a force of one newton is displaced one meter in the direction of the force; and one watt is the power that in one second gives rise to the production of energy of one joule.

The same simplified system of units can be used by the research scientist, the technician, the practicing engineer, and by members of the lay public.

2. The International System of Units

SI rests on seven base units and a number of derived units, some of which have special names. A list of these units is given in the introduction to this volume.

2.1. Base Units

2.1.1. Meter

The meter is the length of the path traveled by light in a vacuum during a time interval of 1/299 792 458 of a second.

This definition, adopted in 1983 by the 17th CGPM, superseded the definition based on the wavelength of a krypton-86 radiation.

2.1.2. Kilogram

The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

This international prototype, adopted by the 1st and 3rd CGPM in 1889 and 1901, is a particular cylinder of platinum–iridium kept at the International Bureau of Weights and Measures near Paris. It is the only base unit still defined by an artifact.

2.1.3. Second

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 cesium-133 atom.

This definition was adopted by the 13th CGPM in 1967 to replace previous definitions based on the mean solar day and, later, the tropical year.

2.1.4. Ampere

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

This definition was adopted by the 9th CGPM in 1948. The electrical units for current and resistance had been first introduced by the International Electrical Congress in 1893. These international units were replaced officially by so-called absolute units by the 9th CGPM.

2.1.5. Kelvin

The kelvin unit of thermodynamic temperature is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water (0.01°C).

Before the 13th CGPM in 1967, when this definition was adopted, the unit was called the degree Kelvin (symbol °K, now K).

2.1.6. Mole

The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12.

When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

This definition was adopted by the 14th CGPM in 1971. Previously, physicists and chemists had based the amount of substance, then called gram–atom or gram–molecule, on the atomic weight of oxygen (by general agreement taken as 16), but with slight differences depending on the isotope used. The 1971 agreement assigned the value of 12 to the isotope 12 of carbon to give a unified scale. At its 1980 meeting, the International Committee for Weights and Measures (CIPM), under the authority of the CGPM, specified that in this definition "it is understood that unbound atoms of carbon-12, at rest and in their ground state, are referred to."

2.1.7. Candela

The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

This unit, most recently defined by the 16th CGPM in 1979, replaced the candle and, later, the new candle and a definition of the candela based on the luminous intensity of a specified projected area of a blackbody emitter at the temperature of freezing platinum.

2.2. Derived Units

The largest class of SI units, the derived units, consists of a combination of base and derived units according to the algebraic relations linking the corresponding quantities. When two or more units expressed in base units are multiplied or divided to obtain derived quantities, the result is a unit value. The fact that no numerical constant is introduced maintains this coherent system. Special names have been given to 21 derived units. For example, the joule is the name given to the product of a newton and a meter; the siemens is the name given to the quotient of an ampere divided by a volt. A list of derived SI units is given in the introduction to this volume (pp. xiv–xvi). The SI units with special names and their definitions are given in Table 1.

2.3. Prefixes

In SI, 20 prefixes are used and are directly attached to form decimal multiples and submultiples of the units (see the introduction to this volume, p. xvi). Prefixes indicate the order of magnitude, thus eliminating nonsignificant digits and providing an alternative to powers of 10; eg, 45 300 kPa becomes 45.3 MPa and 0.0043 m becomes 4.3 mm.

Preferably, the prefix should be selected in such a way that the resulting value lies between 0.1 and 1000. To minimize variety, it is recommended that prefixes representing 1000 raised to an integral power be used. For example, lengths can be expressed in micrometers, millimeters, meters, or kilometers and still meet the 0.1-to-1000 limits. There are three exceptions to these rules: (*1*) In expressing area and volume, the intermediate prefixes may be required, eg, hm^2, dL, and cm^3. (*2*) In tables of values, for comparison purposes it is generally preferable to use the same multiple throughout, and one particular multiple is also used in some applications. For example, millimeter is used for linear dimensions in mechanical engineering drawings even when the values are far outside the range 0.1 to 1000 mm. (*3*) The centimeter is often used for body-related measurements, eg, clothing.

2.3.1. Compound Units

It is usually recommended that only one prefix be used in forming a multiple of a compound unit, and that it should be attached to the numerator. An exception is the base unit kilogram, where it appears in the denominator. Multiples of kilogram are formed by attaching the prefix to the word gram (g). Compound prefixes are not used; eg, 1 pF is correct, not 1 $\mu\mu$F.

2.4. Units Used with SI

A number of non-SI units are used in SI (Table 2).

2.4.1. Time

Although the SI unit of time is the second, the minute, hour, day, and other calendar units may be necessary where time relates to calendar cycles. Automobile velocity is, for example, expressed in kilometers per hour.

2.4.2. Plane Angle

The radian, although the preferred SI unit, is not always convenient, and the use of the degree is permissible. Minute and second should be reserved for special fields such as cartography.

2.4.3. Volume

The special name liter (L) has been approved for the cubic decimeter, but its use is restricted to volumetric capacity, dry measure, and measure of fluids (both gases and liquids).

2.4.4. Mass

The metric ton (symbol t), equal to 1000 kg, is used widely in commerce, although the megagram (Mg) is the appropriate SI unit.

Table 1. SI Derived Units with Special Names

Quantity	Name	Symbol	Formula	Definition
absorbed dose	gray[a]	Gy	J/kg	absorbed dose when energy per unit mass imparted to matter by ionizing radiation is one joule per kilogram
activity	becquerel	Bq	1/s	activity of radionuclide decaying at rate of one spontaneous nuclear transition per second
angle				
plane	radian	rad		plane angle between two radii of a circle that cut off on the circumference an arc equal in length to the radius
solid	steradian	sr		solid angle that, having its vertex in the center of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere
Celsius temperature	degree Celsius	°C		equal to kelvin and used in place of kelvin for expressing Celsius temperature, t, defined by equation $t = T - T_0$, where T is the thermodynamic temperature and $T_0 = 273.15$ K by definition
dose equivalent	sievert	Sv	J/kg	dose equivalent when absorbed dose of ionizing radiation multiplied by dimensionless factors Q (quality factor) and N (product of any other multiplying factors) stipu-lated by the International Commission on Radiological Protection is one joule per kilogram
electric capacitance	farad	F	C/V	capacitance of a capacitor between plates of which there appears a difference of potential of one volt when charged by a quantity of electricity equal to one coulomb
electric charge, quantity of electricity	coulomb	C	A·s	quantity of electricity transported in one second by current nof one ampere
electric conductance	siemens	S	A/V	electric conductance of a conductor in which current of one ampere is produced by electric potential difference of one volt
electric inductance	henry	H	Wb/A	inductance of a closed circuit in which electromotive force of one volt is produced when electric current in circuit varies uniformly at rate of one ampere per second
electric potential, potential difference, electromotive force	volt	V	W/A	difference of electric potential between two points of con-ductor carrying constant current of one ampere, when power dissipated between these points is equal to one watt
electric resistance	ohm	Ω	V/A	electric resistance between two points of conductor when constant difference of potential of one volt, applied between these two points, produces in this conductor a current of one ampere, this conductor not being the source of any electromotive force
energy, work, quantity of heat	joule	J	N·m	work done when point of application of force of one newton is displaced a distance of one meter in the direction of force
force	newton	N	$kg{\cdot}m/s^2$	that force which, when applied to a body having mass of one kilogram, gives it acceleratiion of one meter per second squared
frequency	hertz	Hz	1/s	frequency of periodic phenomenon of which period is one second
illuminance	lux	lx	lm/m^2	illuminance produced by luminous flux of one lumen uniformly distributed over surface of one square meter
luminous flux	lumen	lm	cd·sr	luminous flux emitted in a solid angle of one steradian by point source having uniform intensity of one candela
magnetic flux	weber	Wb	V·s	magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of one volt as it is reduced to zero at uniform rate in one second
magnetic flux density	tesla	T	Wb/m^2	magnetic flux density given by magnetic flux of one weber per square meter
power, radiant flux	watt	W	J/s	power which gives rise to the production of energy at rate of one joule per second
pressure or stress	pascal	Pa	N/m^2	pressure or stress of one newton per square meter

[a]The gray is also used for the ionizing radiation quantities, specific energy imparted, kerma, and absorbed dose index, which have the SI unit joule per kilogram.

Table 2. Units in Use with SI

Unit	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
degree	$^\circ$	$1^\circ = (\pi/180)$ rad
minute	$'$	$1' = (1/60)^\circ = (\pi/10800)$ rad
second	$''$	$1'' = (1/60)' = (\pi/648000)$ rad
liter	L	1 L = 1 $dm^3 = 10^{-3}\ m^3$
metric ton	t	1t = 10^3 kg

Table 3. Units Temporarily in Use with SI

Unit	Symbol	Value in SI units
nautical mile		1nautical mile = 1852 m
knot		1nautical mile per hour = (1852/3600) m/s
hectare	ha	1 ha = 1 $hm^2 = 10^4\ m^2$
kilowatt-hour	kWh	1 kWh = 3.6 MJ
barn	b	1 b = $10^{-28}\ m^2$
bar	bar	1bar = 10^5 Pa
curie	Ci	1 Ci = 3.7×10^{10} Bq
roentgen	R	1 R = 2.58×10^{-4} C/kg
rad	rd	1 rd = 0.01 Gy
rem	rem	1 rem = 0.01 Sv = 10 mSv

2.5. Units Used Temporarily with SI

Additional non-SI units are used with SI units until the CIPM considers their use no longer necessary (Table 3).

2.5.1. Length

The nautical mile is a special unit employed for marine and aerial navigation to express distances. The conventional value was adopted by the 1st International Extraordinary Hydrographic Conference, Monaco, 1929, under the name International nautical mile.

2.5.2. Area

The SI unit of area is the square meter (m^2). The hectare (ha) is a special name for the square hectometer (hm^2). Large land or water areas are generally expressed in hectares or in square kilometers (km^2).

2.5.3. Energy

The kilowatthour (kWh) is widely used as a measure of electric energy, but it should eventually be replaced by the megajoule (MJ) (1 kWh = 3.6 MJ).

2.5.4. Pressure

Although both bar and torr are widely used for pressure, the use of the torr is strongly discouraged in favor of the pascal and its multiples. The bar, however, is still approved for temporary use. The millibar is widely used in meteorology (1 mbar = 100 Pa).

2.5.5. Radiation Units

Units in use for activity of a radionuclide, ie, the curie, the roentgen (exposure to x and gamma rays), the rad (absorbed dose), and the rem (dose equivalent), should eventually be replaced by the becquerel (Bq), coulomb per kilogram (C/kg), gray (Gy), and the sievert (Sv), respectively.

2.6. Units to Be Abandoned

Except for the non-SI units referred to in the two preceding sections, a great many other metric units should be avoided in order to maintain the advantages of using one common coherent system of units, eg, units of the cgs system with special names such as the erg, dyne, poise, stokes, gauss, oersted, maxwell, stilb, phot, and angstrom. Other unit names to be deprecated are the kilogram-force, calorie, torr, millimeter of mercury, and the mho (see also pp. xxvi–xxvii in this *Encyclopedia*).

2.7. Mass, Force, and Weight

Weight is a force: the weight of a body is the product of its mass and the acceleration due to gravity.

The use of the same term for units of force and mass causes confusion. When the non-SI units are used, a distinction should be made between force and mass, eg, lbf to denote force in gravimetric engineering units, and lb for mass.

The term load means either mass or force, depending on its use. A load that produces a vertically downward force because of the influence of gravity acting on a mass may be expressed in mass units. Any other load is expressed in force units.

2.8. Temperature

The kelvin is the SI unit of thermodynamic temperature, and is generally used in scientific calculations. Wide use is made of the degree Celsius (°C) for both temperature and temperature interval. The temperature interval 1°C equals 1 K exactly. Celsius temperature, t, is related to thermodynamic temperature, T, by the following equation:

$$t = T - 273.15$$

The name degree centigrade was dropped in 1948 in favor of the degree Celsius because in some countries the grade has been used as a unit of angular measure.

2.9. Pressure and Vacuum

Pressure is usually designated as gauge pressure, absolute pressure, or, if below ambient, vacuum. Pressures are expressed in pascals with appropriate prefixes. When the term vacuum is used, it should be made clear whether negative gauge pressure or absolute pressure is meant. The correct way to express pressure readings is “at a gauge pressure of 13 kPa” or “at an absolute pressure of 13 kPa.”

2.10. Quantities and Units Used in Rotational Mechanics

2.10.1. Angle, Angular Velocity, and Angular Acceleration

Their SI units are rad, rad/s, and rad/s^2, respectively. Because the radian is here taken to be dimensionless, the units 1, 1/s, and 1/s^2 are also used where appropriate.

2.10.2. Moment of Force (Torque or Bending Moment)

Moment of force is force times moment arm (lever arm). Its SI unit is $N{\cdot}m$.

2.10.3. Moment of Inertia

Moment of inertia, I, is a property of the mass distribution of a body around an axis ($I = \Sigma mr^2$). Its SI unit is $kg{\cdot}m^2$.

2.10.4. Angular Momentum (Moment of Momentum)

Angular momentum is linear momentum ($kg{\cdot}m/s$) times moment arm (m). Its SI unit is $kg{\cdot}m^2/s$. For a rotating body the total angular momentum is equal to the moment of inertia I ($kg{\cdot}m^2$) times the angular velocity Ω (rad/s or 1/s).

2.10.5. Rotational Kinetic Energy

Rotational kinetic energy of a rotating body is equal to 1/2 $I\ \Omega^2$. Its SI unit is J.

2.10.6. Rotational Work

Rotational work is equal to torque ($N{\cdot}m$) times angle of rotation (rad). Its SI unit is J.

2.10.7. Torsional Stiffness (Torsion Constant)

Torsional stiffness of a body is applied torque ($N{\cdot}m$) divided by angle of twist (rad). Its SI unit is $N{\cdot}m/rad$.

2.10.8. Centripetal Acceleration

Centripetal acceleration, v^2/r or $\Omega^2 r$, where v is the tangential linear velocity (m/s), r the radius (m), and Ω the angular velocity (rad/s), is, like any other linear acceleration, measured in SI units m/s^2. Centripetal force, equal to mass times centripetal acceleration, is, like any force in SI, measured in newtons.

2.11. Impact Energy Absorption

This quantity, often incorrectly called impact resistance or impact strength, is measured in terms of the work required to break a standard specimen; the proper unit is joule.

2.12. Nominal Dimensions

Some dimensions do not have an SI equivalent because their values are nominal, that is, a value is assigned for the purpose of convenient designation. For example, a 1-in. pipe has no dimension that is 25.4 mm. Another common example is the 2-by-4 piece of lumber, which is considerably smaller than 50.8 by 101.6 mm in its finished form.

2.13. Dimensionless Quantities

Certain quantities, eg, refractive index and relative density (formerly specific gravity), are expressed by pure numbers. In these cases, the corresponding SI unit is the ratio of the same two SI units, which cancel each other, leaving a dimensionless unit. The SI unit of dimensionless quantities may be expressed as 1. Units for dimensionless quantities such as percent and parts per million (ppm) may also be used with SI; in the latter case, it is important to indicate whether the parts per million are by volume or by mass.

2.13.1. Density and Relative Density

Density is mass per unit volume and in SI is normally expressed as kilograms per cubic meter (density of water = 1000 kg/m^3 or 1 g/cm^3). The term specific gravity was formerly the accepted dimensionless value describing the ratio of the density of solids and liquids to the density of water at 4°C or for gases to the density of air at standard conditions. The term specific gravity is being replaced by relative mass density, a more descriptive term.

2.14. Style and Usage

If the advantages of SI are to be realized, everyone must use the system in the same manner. Listed below are a number of editorial rules that must be followed:

(1) SI symbols are always in roman type, not italics.
(2) A space is required between the number and the unit, eg, 150 mm, not 150mm.
(3) A period is not placed after a symbol unless the symbol is at the end of a sentence.
(4) The plural form of a symbol is the same as the singular. Plurals of unit names are formed by adding an "s", except in henries; hertz, lux, and siemens are not changed.
(5) Y, Z, E, P, T, G, and M, the prefixes for 10^6 and above, are capitalized, as are the symbols whose unit names have been derived from proper names, eg, N for newton (Sir Isaac Newton) and Pa for pascal (Blaise Pascal); an exception is the use of L for liter.
(6) The product of two or more symbols is indicated by a centered dot and the product of unit names preferably by just a space, eg, N·m for newton meter.
(7) A solidus indicates the quotient of two unit symbols and the word per the division of two unit names: m/s for meter per second. The horizontal line or negative powers are also permissible. The solidus or the word per is not repeated in the same expression, eg, acceleration as m/s^2 for meter per second squared and thermal conductivity as W/(m·K) for watt per meter kelvin.
(8) An exponent attached to a symbol containing a prefix indicates that the multiple of the unit is raised to the power expressed by the exponent, eg, $1\ cm^3 = (10^{-2}\ m)^3 = 10^{-6}\ m^3$.
(9) Compound prefixes are not used, eg, pF, not $\mu\mu$F.
(10) Because the comma is used as a decimal marker in many countries, a comma should not be used to separate groups of digits. The digits can be separated into groups of three to the left and right of the decimal point, and a space separates the groups, eg, 1234567 or 0.123456. If there are only four digits, the space can be deleted; eg, 1.1234.
(11) Because of the difference in the meaning of the word billion in the United States and most other countries, this term must be avoided; the prefix giga is unambiguous.
(12) When using powers with a unit name, the modifier squared or cubed is used after the unit name, except for areas and volumes, eg, second squared, gram cubed, but square millimeter, cubic meter.

2.15. Conversion and Rounding

Conversion of quantities should be handled with careful regard to the implied correspondence between the accuracy of the data and the number of digits. In all soft conversions (a soft conversion being defined as the conversion of an existing non-SI measurements to acceptable SI units without a significant change in size or magnitude), the number of significant digits retained should be such that accuracy is neither sacrificed nor exaggerated. Following are some examples.

Table 4. Rounding of Linear Units

Original tolerance, inches		
At least	Less than	Fineness of rounding, mm
0.00004	0.0004	0.0001
0.0004	0.004	0.001
0.004	0.04	0.01
0.04	0.4	0.1
0.4		1

Table 5. Temperature Conversion Tolerances

°F	K or °C
2 ± 1	1 ± 0.5
4 ± 2	2 ± 1
10 ± 5	6 ± 3
20 ± 10	11 ± 5.5
30 ± 15	17 ± 8.5
40 ± 20	22 ± 11
50 ± 25	28 ± 14

A length is reported as 75 ft. The exact metric conversion is 22.86 m. If the reported length is a value rounded to the nearest 1 ft, it would be more appropriate to round the metric value to the nearest 0.1 m, ie, 22.9 m. If the 75-ft length, however, was rounded to the nearest 5 ft, then the appropriate rounding would be to the nearest 1 m, or 23 m.

2.15.1. Significant Digits

Any digit that is necessary to define the specific value or quantity is said to be significant. A problem arises, however, when a value of, eg, 4 in. is given. This may be intended to represent 4, 4.0, 4.00, 4.000 or even more accuracy with a corresponding increase in significant digits (equivalent to 102, 101.6, 101.60, and 101.600 mm, respectively).

2.15.2. Tolerances

2.15.2.1. Linear Units. The following procedure is used for converting linear units to the proper number of significant places: the maximum and minimum limits in inches are calculated. The corresponding two values are converted exactly into millimeters by multiplying each by the conversion factor 1 in. = 25.4 mm. The results are rounded in accordance with Table 4.

2.15.2.2. Temperature. General guidance for converting tolerances from degrees Fahrenheit to kelvins or degrees Celsius is given in Table 5.

2.15.2.3. Pressure or Stress. Values with an uncertainty of more than 2% may be converted without rounding by using the approximate factor $1\ \text{lbf/in.}^2 = 7\ \text{kPa}$.

2.16. Conversion Factors

Excellent tables of conversion factors are available (1–3), in which the conversion factors are listed both alphabetically and classified by physical quantity.

The conversion factors are presented for ready adaptation to computer readout and electronic data transmission. The factors are written as a number equal to or greater than one and less than 10, with six or fewer decimal places. The number is followed by E (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example:

$$3.523\,907\ \text{E}{-}02 = 3.523\,907 \times 10^{-2} = 0.035\,239\,07$$

An asterisk (*) after the sixth decimal place indicates that the conversion factor is exact and that all subsequent digits are zero. Where fewer than six decimal places are shown, more precision is not warranted.

The conversion factors for other compound units not listed can easily be generated from numbers given in the alphabetical list by the substitution of the converted units; eg, to find the conversion factor from lb·ft/s to kg·m/s:

$$1\ \text{lb} = 0.453\,592\,4\ \text{kg}$$

$$1\ \text{ft} = 0.3048\ \text{m}\ \ \text{(exactly)}$$

Substituting,

$$(0.453\,592\,4\ \text{kg}) \times (0.3048\ \text{m})/\text{s} = 0.138\,255\,0\ \text{kg·m/s}$$

Thus, the factor is 1.382 550 E-01.

To find the conversion factor from oz·in.^2 to kg·m^2,

$$1\ \text{oz} = 0.028\,349\,52\ \text{kg}$$

$$1\ \text{in.}^2 = 0.000\,645\,16\ \text{m}^2\ \ \text{(exactly)}$$

Substituting,

$$(0.028\,349\,52\ \text{kg}) \times \left(0.000\,645\,16\ \text{m}^2\right) = 0.000\,018\,289\,98\ \text{kg·m}^2$$

Thus, the factor is 1.828 998 E-05.

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