Excerpts from Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)[1]

Following are excerpts from Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System E 380, which is available as a separate publication and which appears in its entirety in Volume 14.02. Deleted are appendixes X1, X2, X3, and X4. Added is a table of selected conversion factors from Appendix X3.

CONTENTS

1. Scope

1.1 This standard gives guidance for application of The International System of Units (the modernized metric system) developed and maintained by the General Conference on Weights and Measures (abbreviated CGPM from the official French name Conférence Générale des Poids et Mesures). The name International System of Units and the international abbreviation SI[2] were adopted by the 11th CGPM in 1960.

1.2 Information is included on SI, a limited list of non-SI units recognized for use with SI units, and a list of conversion factors from non-SI to SI units, together with general guidance on proper style and usage.

1.3 It is hoped that an understanding of the system and its characteristics, and careful use according to this standard, will help to avoid the degradation that has occurred in all older measurement systems.

2. Terminology

2.1 To help ensure consistently reliable conversion and rounding practices, a clear understanding of the related nontechnical terms is a prerequisite.

2.2 Certain terms used in this standard are defined as follows:

accuracy (as distinguished from **precision**)—the degree of conformity of a measured or calculated value to some recognized standard or specified value. This concept involves the systematic error of an operation, which is seldom negligible.

approximate value—a value that is nearly but not exactly correct or accurate.

coherent system of units—a system of units of measurement in which a small number of base units, defined as dimensionally independent, are used to derive all other units in the system by rules of multiplication and division with no

[1] This standard is under the jurisdiction of ASTM Committee E-43 on Metric Practice and is the direct responsibility of Subcommittee E43.10 on Standards.

Current edition approved August 15, 1993. Published October 1993. Originally published in 1964 without designation as ASTM *Metric Practice Guide*, revised 1966. Adopted as standard 1968. Last previous edition E 380 – 92.

[2] From the French name, Le Système International d'Unités.

numerical factors other than unity (see Appendix X1.9).

deviation—variation from a specified dimension or design requirement, usually defining upper and lower limits (see also **tolerance**).

digit—one of the ten arabic numerals (0 to 9).

dimension—a geometric element in a design, such as length or angle, or the magnitude of such a quantity.

feature—an individual characteristic of a part, such as screw-thread, taper, or slot.

figure (numerical)—an arithmetic value expressed by one or more digits.

inch-pound units—units based upon the yard and the pound commonly used in the United States of America and defined by the National Institute of Standards and Technology. Note that units having the same names in other countries may differ in magnitude.

nominal value—a value assigned for the purpose of convenient designation; existing in name only.

precision (as distinguished from **accuracy**)—the degree of mutual agreement between individual measurements, namely repeatability and reproducibility.

significant digit—any digit that is necessary to define a value or quantity (see 5.3).

tolerance—the total amount by which a quantity is allowed to vary; thus the tolerance is the algebraic difference between the maximum and minimum limits.

3. SI Units and Symbols

3.1 *Classes of Units*—SI units are divided into three classes:

base units
supplementary units
derived units

3.2 *Base Units*—SI is based on seven well-defined units (see Table 1) which by convention are regarded as dimensionally independent.

3.3 *Supplementary Units*—This class contains two units, the radian and the steradian (see Table 2). At the time of the introduction of the International System, the 11th CGPM left open the question of the nature of these supplementary units. Considering that plane angle is generally expressed as the ratio between two lengths and solid angle as the ratio between an area and the square of length, the CIPM (1980) specified that in the International System the quantities plane angle and solid angle should be considered as dimensionless derived quantities. Therefore, the supplementary units radian and steradian are to be regarded as dimensionless derived units which may be used or omitted in the expressions for derived units.

TABLE 1 Base SI Units

Quantity[3]	Unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature[A]	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

[A] For a discussion of Celsius temperature see 4.4.2.

TABLE 2 Supplementary SI Units

Quantity[3]	Unit	Symbol
plane angle	radian	rad
solid angle	steradian	sr

TABLE 3 Derived SI Units with Special Names

Quantity[3]	Unit	Symbol	Formula
frequency (of a periodic phenomenon)	hertz	Hz	1/s
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, potential difference, electromotive force	volt	V	W/A
electric capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
electric 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
Celsius temperature	degree Celsius[A]	°C	K[see 4.4.2]
luminous flux	lumen	lm	$cd \cdot sr$
illuminance	lux	lx	lm/m^2
activity (of a radionuclide)	becquerel	Bq	1/s
absorbed dose[B]	gray	Gy	J/kg
dose equivalent	sievert	Sv	J/kg

[A] Inclusion in the table of derived SI units with special names approved by the CIPM in 1976.

[B] Related quantities using the same unit are: specific energy imparted, kerma, and absorbed dose index.

3.4 *Derived Units:*

3.4.1 Derived units are formed by combining base units, supplementary units, and other derived units according to the algebraic relations linking the corresponding quantities. The symbols for derived units are obtained by means of the mathematical signs for multiplication, division, and use of exponents. For example, the SI unit for velocity is the metre per second (m/s or $m \cdot s^{-1}$), and that for angular velocity is the radian per second (rad/s or $rad \cdot s^{-1}$).

3.4.2 Those derived SI units which have special names and symbols approved by the CGPM are listed in Table 3.

3.4.3 It is frequently advantageous to express derived units in terms of other derived units with special names; for example, the SI unit for electric dipole moment is usually expressed as $C \cdot m$ instead of $A \cdot s \cdot m$.

3.4.4 Some common derived units are listed in Table 4.

3.5 *SI Prefixes* (see 3.2 for application):

3.5.1 The prefixes and symbols listed in Table 5 are used to form names and symbols of the decimal multiples and submultiples of the SI units except for kilogram.

3.5.2 *Unit of Mass*—Among the base and derived units of SI, the unit of mass (kilogram) is the only one whose name, for historical reasons, contains a prefix. Names of decimal

[3] "Quantity" as used in the headings of the tables of this standard means measurable attribute of phenomena or matter.

TABLE 4 Some Common Derived Units of SI

Quantity[3]	Unit	Symbol
absorbed dose rate	gray per second	Gy/s
acceleration	metre per second squared	m/s²
angular acceleration	radian per second squared	rad/s²
angular velocity	radian per second	rad/s
area	square metre	m²
concentration (of amount of substance)	mole per cubic metre	mol/m³
current density	ampere per square metre	A/m²
density, mass	kilogram per cubic metre	kg/m³
electric charge density	coulomb per cubic metre	C/m³
electric field strength	volt per metre	V/m
electric flux density	coulomb per square metre	C/m²
energy density	joule per cubic metre	J/m³
entropy	joule per kelvin	J/K
exposure (X and gamma rays)	coulomb per kilogram	C/kg
heat capacity	joule per kelvin	J/K
heat flux density irradiance	watt per square metre	W/m²
luminance	candela per square metre	cd/m²
magnetic field strength	ampere per metre	A/m
molar energy	joule per mole	J/mol
molar entropy	joule per mole kelvin	J/(mol·K)
molar heat capacity	joule per mole kelvin	J/(mol·K)
moment of force[A]	newton metre	N·m
permeability (magnetic)	henry per metre	H/m
permittivity	farad per metre	F/m
power density	watt per square metre	W/m²
radiance	watt per square metre steradian	W/(m²·sr)
radiant intensity	watt per steradian	W/sr
specific heat capacity	joule per kilogram kelvin	J/(kg·K)
specific energy	joule per kilogram	J/kg
specific entropy	joule per kilogram kelvin	J/(kg·K)
specific volume	cubic metre per kilogram	m³/kg
surface tension	newton per metre	N/m
thermal conductivity	watt per metre kelvin	W/(m·K)
velocity	metre per second	m/s
viscosity, dynamic	pascal second	Pa·s
viscosity, kinematic	square metre per second	m²/s
volume	cubic metre	m³
wave number	1 per metre	1/m

[A] See 4.4.4.

multiples and submultiples of the unit of mass are formed by attaching prefixes to the word *gram* (g).

3.5.3 These prefixes or their symbols are directly attached to names or symbols of units, forming multiples and submultiples of the units. In strict terms these must be called "multiples and submultiples of SI units," particularly in discussing the coherence of the system (see Section 2). In common parlance, the base units and derived units, along with their multiples and submultiples, are all called SI units.

4. Application of the Metric System

4.1 *General*—SI is the form of the metric system that is preferred for all applications. It is important that this modernized form of the metric system be thoroughly understood and properly applied. Obsolete metric units and practices are widespread, particularly in those countries that long ago adopted the metric system, and much usage is improper. This section gives guidance concerning the limited number of cases in which units outside SI are appropriately used, and makes recommendations concerning usage and style.

4.2 *Application of SI Prefixes:*

4.2.1 *General*—In general the SI prefixes (3.5) should be used to indicate orders of magnitude, thus eliminating nonsignificant digits and leading zeros in decimal fractions, and providing a convenient alternative to the powers-of-ten notation preferred in computation. For example:

12 300 mm becomes 12.3 m
12.3 × 10³ m becomes 12.3 km
0.00123 µA becomes 1.23 nA

4.2.2 *Selection*—When expressing a quantity by a numerical value and a unit, a prefix should preferably be chosen so that the numerical value lies between 0.1 and 1000. To minimize variety, it is recommended that prefixes representing 1000 raised to an integral power be used. However, three factors may justify deviation from the above:

4.2.2.1 In expressing area and volume, the prefixes hecto-, deka-, deci-, and centi- may be required, for example, square hectometre, cubic centimetre.

4.2.2.2 In tables of values of the same quantity, or in a discussion of such values within a given context, it is generally preferable to use the same unit multiple throughout.

4.2.2.3 For certain quantities in particular applications, one particular multiple is customarily used. For example, the millimetre is used for linear dimensions in mechanical engineering drawings even when the values lie far outside the range 0.1 to 1000 mm; the centimetre is often used for body measurements and clothing sizes.

4.2.3 *Prefixes in Compound Units*[4]—It is recommended that only one prefix be used in forming a multiple of a compound unit. Normally the prefix should be attached to a unit in the numerator. One exception to this is when the kilogram occurs in the denominator.

Examples:

V/m, *not* mV/mm, and MJ/kg, *not* kJ/g

4.2.4 *Compound Prefixes*—Compound prefixes, formed by the juxtaposition of two or more SI prefixes, are not to be used. For example, use

1 nm, *not* 1 mμm
1 pF, *not* 1 μμF

If values are required outside the range covered by the prefixes, they should be expressed by using powers of ten applied to the base unit.

4.2.5 *Powers of Units*—An exponent attached to a symbol containing a prefix indicates that the multiple or submultiple of the unit (the unit with its prefix) is raised to the power expressed by the exponent. For example:

$$1\ cm^3 = (10^{-2}\ m)^3 = 10^{-6}\ m^3$$
$$1\ ns^{-1} = (10^{-9}\ s)^{-1} = 10^{9}\ s^{-1}$$
$$1\ mm^2/s = (10^{-3}\ m)^2/s = 10^{-6}\ m^2/s$$

4.2.6 *Calculations*—Errors in calculations can be minimized if the base and the coherent derived SI units are used and the resulting numerical values are expressed in powers-of-ten notation instead of using prefixes.

4.3 *Other Units:*

4.3.1 *Units from Different Systems*—To assist in preserving the advantage of SI as a coherent system, it is advisable to minimize the use with it of units from other systems. Such use should be limited to units listed in this section.

4.3.2 *Units in Use with SI (see Table 6):*

4.3.2.1 *Time*—The SI unit of time is the second. This unit is preferred and should be used if practical, particularly when technical calculations are involved. In cases where time relates to life customs or calendar cycles, the minute, hour, day, and other calendar units may be necessary. For example, vehicle speed will normally be expressed in kilometres per hour.

4.3.2.2 *Plane Angle*—The SI unit for plane angle is the radian. Use of the degree and its decimal submultiples is permissible when the radian is not a convenient unit. Use of the minute and second is discouraged except for special fields such as cartography.

4.3.2.3 *Area*—The SI unit of area is the square metre (m²). The hectare (ha) is a special name for square hectometre (hm²). Large land or water areas are generally expressed in hectares or in square kilometres (km²).

4.3.2.4 *Volume*—The SI unit of volume is the cubic metre (m³). This unit, or one of the regularly formed multiples such as the cubic centimetre, is preferred. The special name *litre*[5] (L)[6] has been approved for the cubic decimetre, but use of this unit is restricted to volumetric capacity, dry measure, and measure of fluids (both gases and liquids). No prefix other than milli- or micro- should be used with litre.

4.3.2.5 *Mass*—The SI unit of mass is the kilogram. This unit, or one of the multiples formed by attaching an SI prefix to *gram* (g), is preferred for all applications. The megagram (Mg) is the appropriate unit for measuring large masses such as have been expressed in tons. However, the name *ton* has been given to several large mass units that are widely used in commerce and technology—the long ton of 2240 lb, the short ton of 2000 lb, and metric ton of 1000 kg (also called the *tonne*). None of these terms are SI. The term *metric ton* should be restricted to commercial usage, and no prefixes should be used with it. Use of the term *tonne* is deprecated.

4.3.3 *Units in Use with SI Temporarily* (see Table 7):

4.3.3.1 *Energy*—The SI unit of energy, the joule, together with its multiples, is preferred for all applications. The kilowatthour is widely used, however, as a measure of electric energy. This unit should not be introduced into any new areas, and eventually it should be replaced by the megajoule.

4.3.3.2 *Pressure and Stress*—The SI unit of pressure and stress is the pascal (newton per square metre) and with

TABLE 5 SI Prefixes

Multiplication Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto[A]	h
10 = 10^{1}	deka[A]	da
0.1 = 10^{-1}	deci[A]	d
0.01 = 10^{-2}	centi[A]	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

[A] To be avoided where practical, except as noted in 4.2.2.

TABLE 6 Units in Use with SI

Quantity[3]	Unit	Symbol	Value in SI Units
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3600 s
	day	d	1 d = 24 h = 86 400 s
	week, month, etc.	...	...
plane angle	degree	°	1° = (π/180) rad
	minute[A]	′	1′ = (1/60)° = (π/10 800) rad
	second[A]	″	1″ = (1/60)′ = (π/648 000) rad
volume	litre[B]	L	1 L = 1 dm³ = 10^{-3} m³
mass	metric ton	t	1 t = 10^{3} kg
area	hectare	ha	1 ha = 1 hm² = 10^{4} m²

[A] Use discouraged except for special fields such as cartography.
[B] See 4.3.2.4.

[4] A compound unit is a derived unit that is expressed in terms of two or more units rather than by a single special name.

[5] See Appendix X1.11.1.

[6] The CGPM in October 1979 approved L and l as alternative symbols for litre. Since the letter symbol l can easily be confused with the numeral 1, only the symbol L is recommended for USA use.

TABLE 7 Units in Use with SI Temporarily

Quantity[3]	Unit	Symbol	Definition
energy [see 4.3.3.1]	kilowatthour	kWh	1 kWh = 3.6 MJ
cross section	barn	b	1 b = 10^{-28} m² = 100 fm²
pressure [see 4.3.3.2]	bar	bar	1 bar = 10^5 Pa
activity (of a radionuclide)	curie	Ci	1 Ci = 3.7×10^{10} Bq
exposure (X and gamma rays)	roentgen	R	1 R = 2.58×10^{-4} C/kg
absorbed dose	rad	rd	1 rd = 0.01 Gy
dose equivalent	rem	rem	1 rem = 0.01 Sv = 10 mSv

proper SI prefixes is applicable to all such measurements. Old metric gravitational units for pressure and stress such as kilogram-force per square centimetre (kgf/cm²) shall not be used. Widespread use has been made of other non-SI units such as bar and torr for pressure, but this use is strongly discouraged. The millibar is widely used in meteorology; this usage will continue for the present in order to permit meteorologists to communicate easily within their profession. The kilopascal should be used in presenting meteorological data to the public.

4.3.4 *Units and Names to Be Abandoned*—A great many metric units other than those of the SI have been defined over the years. Some of these are used only in special fields; others have found broad application in countries that adopted the metric system early. Except for the special cases discussed in the previous sections, non-SI units (as well as special names for multiples or submultiples of SI units) are to be avoided. Various categories of deprecated units are discussed in 4.3.4.1 to 4.3.4.4. The lists are not intended to be complete, but only to indicate more or less prominent examples of each category.

4.3.4.1 *Cgs Units*—All units peculiar to the various cgs systems (measurement systems constructed by using the centimetre, gram, and second as base units) are to be avoided. Among these units are the following, defined for mechanics, fluid mechanics, and photometry: the erg, dyne, gal, poise, stokes, stilb, phot, and lambert. Further use of the cgs units of electricity and magnetism is deprecated. This statement applies to the units designated by the general abbreviations "esu" (for electrostatic cgs unit) and "emu" (for electromagnetic cgs unit), including those units that have been given special names—the gauss, oersted, maxwell, gilbert, biot, and franklin. It also applies to the unit names formed with the prefixes ab- and stat-, for example, the abampere, statvolt, etc.

4.3.4.2 *Decimal Multiples of SI Units*—Those multiples of SI units that cannot be handled by using the SI prefixes are deprecated. Many such examples are covered in subsection 4.3.4.1. An additional example is the angstrom (0.1 nm).

4.3.4.3 *Unit Names to Be Avoided*—Special names for multiples and submultiples of SI units are to be avoided except for the *litre* (4.3.2.4), *metric ton* (4.3.2.5), and *hectare* (4.3.2.3). For example, do not use:

fermi	1 fermi	= 1 fm = 10^{-15} m
micron	1 micron	= 1 μm = 10^{-6} m
millimicron	1 millimicron	= 1 nm = 10^{-9} m
are	1 are	= 1 dam² = 100 m²
gamma (magnetic flux density)	1 gamma	= 1 nT
γ (mass)	1 γ	= 1 μg
λ (volume)	1 λ	= 1 μL = 1 mm³
mho	1 mho	= 1 S
candle	1 candle	= 1 cd
candlepower	1 candlepower	= 1 cd

4.3.4.4 *Miscellaneous Units*—Other non-SI units that are deprecated include the following:

calorie
grade [1 grade = (π/200) rad]
kilogram-force
langley (= 1 cal/cm²)
metric carat
metric horsepower
millimetre of mercury
millimetre, centimetre, metre of water
standard atmosphere
(1 atm = 101.325 kPa)
technical atmosphere
(1 at = 98.0665 kPa)
torr

4.4 *Some Comments Concerning Units:*

4.4.1 *Mass, Force, and Weight:*

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

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

4.4.1.3 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.

4.4.2 *Temperature*—The SI unit of thermodynamic temperature is the kelvin (K), and this unit is properly used for expressing thermodynamic temperature and temperature intervals. Wide use is also made of the degree Celsius (°C), which is the SI unit used for expressing Celsius temperature and temperature intervals. The Celsius scale (formerly called centigrade) is related directly to thermodynamic temperature (kelvins) as follows:

The temperature interval one degree Celsius equals one kelvin exactly. Celsius temperature (t) is related to thermodynamic temperature (T) by the equation:

$$t = T - T_0$$

where $T_0 = 273.15$ K by definition.

The International Temperature Scale (ITS-90) must be recognized in temperature work of extreme precision. See *ASTM STP 565, Evolution of the International Practical Temperature Scale of 1968.*

4.4.3 *Linear Dimensions:*

4.4.3.1 Nominal dimensions name the item; no SI equivalent is required (see Section 2 for definition of "nominal value"). For example, there is nothing "1 in" about a nominal "1-in pipe," the dimensions of which should be converted as follows:

Nominal Size, inches	Outside Diameter, inches (mm)	Wall Thickness, inches (mm) Sch 40	Sch 80	Sch 160
1	1.315 (33.40)	0.133 (3.38)	0.179 (4.55)	0.250 (6.35)

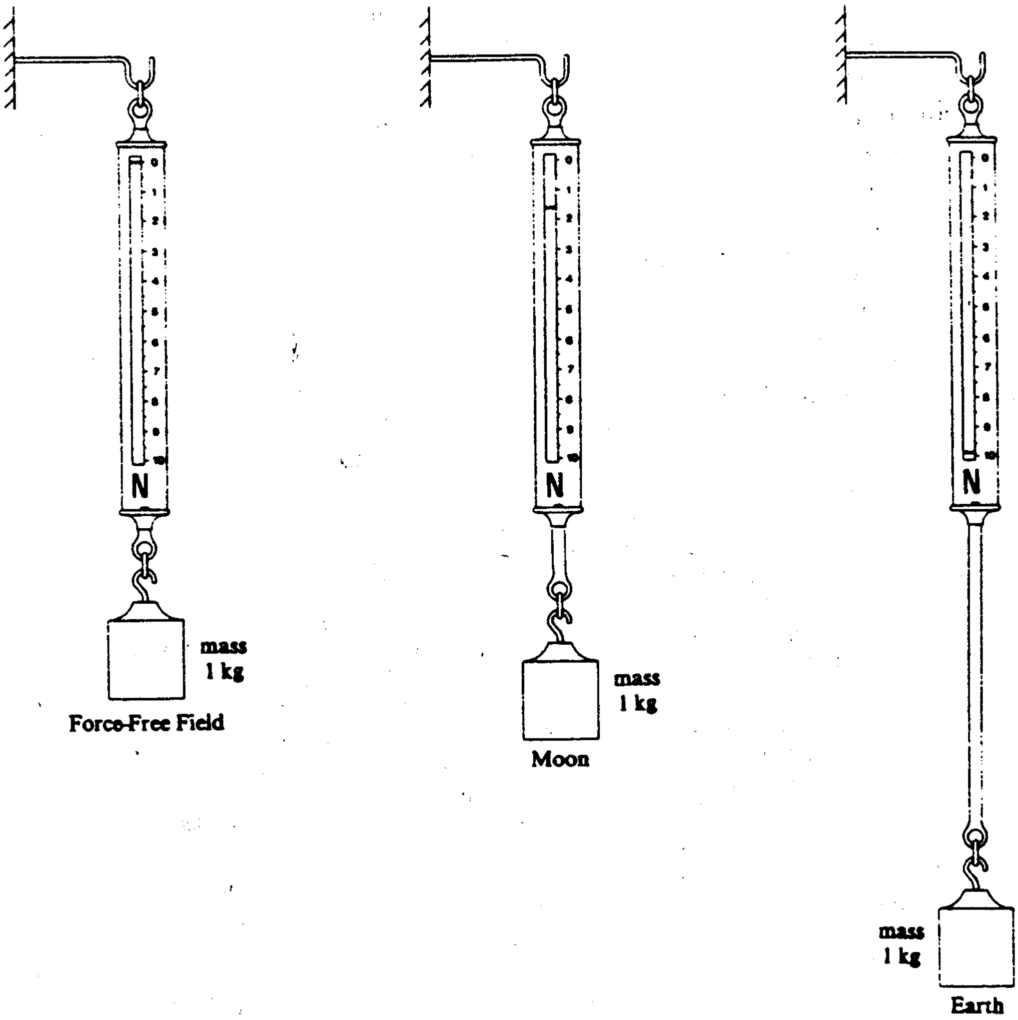

FIG. 1 Illustration of Difference Between Mass (Unit = kilogram = kg) and Force (Unit = newton = N) (see 4.4.1)

Likewise, a "2 by 4" is that in name only and refers to the approximate dimensions in inches of a rough-sawn piece of green lumber, the finished dimensions of which are considerably less. A 1/4-20 UNC screw thread should continue to be identified in this manner. However, the controlling dimensions of the part, such as the pitch, major, and minor diameters of a screw thread, should be converted to SI values in accordance with 5.1 and 5.2.

4.4.3.2 Surface texture should be expressed in micrometres.

4.4.4 *Quantities and Units used in Rotational Mechanics:*

4.4.4.1 *Angle, Angular Velocity, and Angular Acceleration.* Their SI units are rad, rad/s, and rad/s^2 respectively. In accordance with Sec. 3.3, since the radian is here taken to be dimensionless, the units 1, 1/s, and 1/s^2 are also used when appropriate.

4.4.4.2 *Moment of Force* (Torque or Bending Moment) is force times moment arm (lever arm). Its SI unit is N·m.

4.4.4.3 *Moment of Inertia* (I) is a property of the mass distribution of a body about an axis ($I = \Sigma mr^2$). Its SI unit is kg·m^2.

4.4.4.4 *Angular Momentum* (moment of momentum) is linear momentum (kg·m/s) times moment arm (m). Its SI unit is kg·m^2/s. For a rotating body the total angular momentum is equal to the moment of inertia I (kg·m^2) times the angular velocity ω (rad/s or 1/s).

4.4.4.5 *Rotational Kinetic Energy* of a rotating body is equal to $\frac{1}{2}I\omega^2$. Its SI unit is J.

4.4.4.6 *Rotational Work* is equal to torque (N·m) times angle of rotation (rad). Its SI unit is J.

4.4.4.7 *Torsional Stiffness* (torsion constant) of a body is applied torque (N·m) divided by angle of twist (rad). Its SI unit is N·m/rad.

4.4.4.8 *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.

NOTE—*Centripetal Force,* equal to mass times centripetal acceleration, is, like any force in SI, measured in newtons.

4.4.5 *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.

4.4.6 *Pressure and Vacuum*—Gage pressure is absolute pressure minus ambient pressure (usually atmospheric pressure). Both gage pressure and absolute pressure are properly expressed in pascals, using SI prefixes as appropriate. Absolute pressure is never negative. Gage pressure is positive if above ambient pressure and negative if below. Pressure below ambient is often called vacuum; whenever the term *vacuum* is applied to a numerical measure it should be made clear whether negative gage pressure or absolute pressure is meant. See 4.5.5 for methods of designating gage pressure and absolute pressure.

4.4.7 *Dimensionless Quantities:*

4.4.7.1 The values of so-called dimensionless quantities, as for example refractive index and relative permeability, are expressed by pure numbers. In these cases the corresponding SI unit is the ratio of the same two SI units and may be expressed by the number 1.

4.4.7.2 Terms such as percent, parts per thousand, and parts per million may also be used.

4.4.7.3 In all cases, the meaning must be unequivocal. Expressions like "The mole fraction of CO_2 in the sample was 1.2 parts per million" or "The mass fraction of CO_2 in the sample was 1.2 parts per million" are permissible, but would not be permissible if the word "mole" in the first expression or "mass" in the second expression were not present.

4.5 *Style and Usage*—Care must be taken to use unit symbols properly, and international agreement provides uniform rules. Handling of unit names varies because of language differences, but use of the rules included here will improve communications in the United States.

4.5.1 *Rules for Writing Unit Symbols:*

4.5.1.1 Unit symbols should be printed in upright type regardless of the type style used in the surrounding text.

4.5.1.2 Unit symbols are unaltered in the plural.

4.5.1.3 Unit symbols are not followed by a period except when used at the end of a sentence.

4.5.1.4 Letter unit symbols are written in lower-case (for example, cd) unless the unit name has been derived from a proper name, in which case the first letter of the symbol is capitalized (for example, W, Pa). The exception is the symbol for litre, L. Prefix symbols use either lower-case or upper-case letters as shown in 3.5.1. Symbols retain their prescribed form regardless of the surrounding typography. For symbols for use in systems with limited character sets, refer to ANSI X3.50 or ANSI/IEEE 260, as applicable. The symbols in ANSI X3.50 are intended for applications in the field of information processing, where unambiguous transmission of information between computers is required. The symbols in ANSI/IEEE 260 are generally consistent with those in ANSI X3.50 and are intended for communication between human beings. The symbols for limited character sets must never be used when the available character set permits the use of the proper general-use symbols as given in this standard.

4.5.1.5 When a quantity is expressed as a numerical value and a unit symbol, a space should be left between them. For example, use 35 mm, *not* 35mm, and 2.37 lm (for 2.37 lumens), *not* 2.37lm.

Exception: No space is left between the numerical value and the symbols for degree, minute, and second of plane angle, and degree Celsius. For example, use 45°, 20°C.

4.5.1.6 When a quantity expressed as a number and a unit is used in an adjectival sense, it is preferable to use a hyphen instead of a space between the number and the unit name or between the number and the symbol. Examples: A three-metre pole... The length is 3 m... A 35-mm film... The width is 35 mm. However, per 4.5.1.5 Exception, a 90° angle . . . an angle of 90°.

4.5.1.7 No space is used between the prefix and unit symbols.

4.5.1.8 Symbols, not abbreviations, should be used for units. For example, use "A" and not "amp" for ampere.

4.5.2 *Rules for Writing Names:*

4.5.2.1 Spelled-out unit names are treated as common nouns in English. Thus, the first letter of a unit name is not capitalized except at the beginning of a sentence or in capitalized material such as a title.

4.5.2.2 Plurals are used when required by the rules of English grammar and are normally formed regularly, for example, henries for the plural of henry. The following irregular plurals are recommended:

Singular	Plural
lux	lux
hertz	hertz
siemens	siemens

4.5.2.3 No space or hyphen is used between the prefix and unit name. There are three cases where the final vowel in the prefix is commonly omitted: *megohm, kilohm*, and *hectare*. In all other cases where the unit name begins with a vowel both vowels are retained and both are pronounced.

4.5.3 *Units Formed by Multiplication and Division:*

4.5.3.1 With unit names:

Product, use a space (preferred) or hyphen:

newton metre *or* newton-metre

In the case of the watt hour the space may be omitted, thus:

watthour

Quotient, use the word *per* and not a solidus:

metre per second, *not* metre/second

Powers, use the modifier *squared* or *cubed* placed after the unit name:

metre per second squared

In the case of area or volume, the modifier may be placed before the unit name:

square millimetre, cubic metre

This alternative is also allowed for derived units that include area or volume:

watt per square metre

NOTE—To avoid ambiguity in complicated expressions, symbols are preferred over words.

4.5.3.2 With unit symbols:

Product, use a raised dot:

N·m for newton metre

In the case of W·h, the dot may be omitted, thus:

Wh

An exception to this practice is made for computer printouts, automatic typewriter work, etc., where the raised dot is not possible, and a dot on the line may be used.

Quotient, use one of the following forms:

$$\mathrm{m/s} \ or \ \mathrm{m \cdot s^{-1}} \ or \ \frac{\mathrm{m}}{\mathrm{s}}$$

In no case should more than one solidus be used in the same expression unless parentheses are inserted to avoid ambiguity. For example, write:

$$\mathrm{J/(mol \cdot K)} \ or \ \mathrm{J \cdot mol^{-1} \cdot K^{-1}} \ or \ \mathrm{(J/mol)/K},$$

but *not*

$$\mathrm{J/mol/K}$$

4.5.3.3 Symbols and unit names should not be mixed in the same expression. Write:

joules per kilogram *or* J/kg *or* $\mathrm{J \cdot kg^{-1}}$

but *not*

joules/kilogram *nor* joules/kg *nor* $\mathrm{joules \cdot kg^{-1}}$

4.5.4 *Numbers:*

4.5.4.1 The recommended decimal marker is a dot on the line. When writing numbers less than one, a zero should be written before the decimal marker.

4.5.4.2 Outside the United States, the comma is often used as a decimal marker. In some applications, therefore, the common practice in the United States of using the comma to separate digits into groups of three (as in 23,478) may cause ambiguity. To avoid this potential source of confusion, recommended international practice calls for separating the digits into groups of three, counting from the decimal point toward the left and the right, and using a small space to separate the groups. In numbers of four digits on either side of the decimal point the space is usually not necessary, except for uniformity in tables.

Examples:

2.141 596   73 722   7372   0.1335

Where this practice is followed, the space should be narrow (approximately the width of the letter "i"), and the width of the space should be constant even if, as is often the case in printing, variable-width spacing is used between words. Exceptions: In certain specialized applications, such as engineering drawings and financial statements, the practice of using a space for a separator is not customary.

4.5.4.3 Because *billion* means a thousand million (prefix *giga*) in the United States but a million million (prefix *tera*) in most other countries, this term and others, such as trillion, should be avoided in technical writing.

4.5.4.4 Use of M to indicate thousands, as in MCF for thousands of cubic feet, or in MCM for thousands of circular mils, of MM to indicate millions, of C to indicate hundreds, etc., is deprecated because of obvious conflicts with the SI prefixes.

4.5.5 *Attachment*—Attachment of letters to a unit symbol as a means of giving information about the nature of the quantity under consideration is incorrect. Thus MWe for "megawatts electrical (power)," Vac for "volts ac," and kJt for "kilojoules thermal (energy)" are not acceptable. For this reason, no attempt should be made to construct SI equivalents of the abbreviations "psia" and "psig," so often used to distinguish between absolute and gage pressure. If the context leaves any doubt as to which is meant, the word *pressure* must be qualified appropriately. For example:

"... at a gage pressure of 13 kPa"

or

"... at an absolute pressure of 13 kPa"

Where space is limited, such as on gages, nameplates, graph labels, and in table headings, it is permissible to use the unit symbol followed by a space and the modifier in parentheses. For example: V (ac) and V (dc); kPa (gage) and kPa (absolute).

4.5.6 *Pronunciation*—Some recommended pronunciations in English are shown in Table 8.

TABLE 8 Recommended Pronunciation

Prefix	Pronunciation (USA)[A]
exa	ex' a (*a* as in *a*bout)
peta	pet' a (*e* as in p*e*t, *a* as in *a*bout)
tera	as in *terra* firma
giga	jig' a (*i* as in j*i*g, *a* as in *a*bout)
mega	as in *mega*phone
kilo	kill' oh
hecto	heck' toe
deka	deck' a (*a* as in *a*bout)
deci	as in *deci*mal
centi	as in *centi*pede
milli	as in *mili*tary
micro	as in *micro*phone
nano	nan' oh (*an* as in *an*t)
pico	peek' oh
femto	fem' toe (*fem* as in *fem*inine)
atto	as in *a*na*to*my
Selected Units	**Pronunciation**
candela	can *dell'* a
joule	rhyme with *tool*
kilometre	*kill '* oh metre
pascal	rhyme with *rascal*
siemens	same as *seamen's*

[A] The first syllable of every prefix is accented to assure that the prefix will retain its identity. Therefore, the preferred pronunciation of kilometre places the accent on the first syllable, *not* the second.

5. Rules for Conversion and Rounding

5.1 *General:*

5.1.1 Conversion factors to change a value of a quantity expressed in non-SI units to the corresponding value of that quantity expressed in the International System of Units may be exact or approximations adequate for the particular task. The rules in this section are based on using either exact or approximate factors such as those of seven-digit factors listed in Appendix X3. In some cases the quantity is such that factors with fewer digits are appropriate.

5.1.2 Conversion of quantities should be handled with careful regard to the implied correspondence between the accuracy of the data and the given number of digits. In all conversions, the number of significant digits retained should be such that accuracy is neither sacrificed nor exaggerated. (For guidance concerning significant digits see 5.3.) For example, a length of 125 ft converts exactly to 38.1 m. If, however, the 125-ft length had been obtained by rounding to the nearest 5 ft, the conversion should be given as 38 m; and if it had been obtained by rounding to the nearest 25 ft, the conversion should be given as 40 m.

5.1.3 Proper conversion procedure is to multiply a value by a conversion factor that is more accurate than is required; the result is then rounded to the appropriate number of significant digits. For example, to convert 3 feet 2⁹⁄₁₆ inches to metres: (3 × 0.3048) + (2.5625 × 0.0254) = 0.979 487 5 m, which rounds to 0.979 m. Do not round either the conversion factor or the quantity before performing the multiplication, as accuracy may be reduced. After the conversion, the SI value may be expressed by a multiple or submultiple unit of SI by the use of an appropriate prefix, for example, 979 mm.

5.2 *Accuracy and Rounding*—A conversion obtained by multiplying a value by a seven-digit factor usually gives a product with more digits than the original value. The converted value must be rounded to the proper number of significant digits commensurate with the intended accuracy. Conversions usually yield a product with more digits than the original value. The practical aspect of measuring must be considered when using SI equivalents. If a scale having division of ¹⁄₁₆ inch was suitable for making the original measurements, a metric scale having divisions of 1 mm is obviously suitable for measuring in SI units. Similarly, a gage or caliper graduated in divisions of 0.02 mm is comparable to one graduated in divisions of 0.001 in. Analogous situations exist in mass, force, and other measurements. Many techniques are used to guide the determination of the proper number of significant digits in the converted values. Two different approaches to rounding of quantities are here described—one for general use and the other for conversion of dimensions involving mechanical interchangeability.

5.2.1 *General Conversion*—This approach depends on first establishing the intended precision or accuracy of the quantity as a necessary guide to the number of digits to retain. This precision should relate to the number of digits in the original, but in many cases this is not a reliable indicator. A figure 1.1875 may be a very accurate decimalization of a noncritical 1³⁄₁₆ that should have been expressed 1.19. On the other hand, the value 2 may mean "about 2," or it may mean a very accurate value of 2 which should have been written 2.0000. It is therefore necessary to determine the intended precision of a quantity before converting. This estimate of intended precision should never be smaller than the accuracy of measurement and should usually be smaller than one tenth the tolerance if one exists. After estimating the precision of the dimension, the converted dimension should be rounded to a minimum number of significant digits (see 5.3) such that a unit of the last place is equal to or smaller than the converted precision. Examples:

1. A stirring rod 6 in long. In this case, precision is estimated to be about ½ in (± ¼ in). Converted, this is 12.7 mm. The converted dimension 152.4 mm should be rounded to the nearest 10 mm, or 150 mm.

2. 50 000 lbf/in^2 (psi) tensile strength. In this case, precision is estimated to be about ± 200 lbf/in^2 (± 1.4 MPa) based on an accuracy of ± 0.25 % for the tensile tester and other factors. Therefore, the converted dimension, 344.7379 MPa, should be rounded to the nearest whole unit, 345 MPa.

3. Test pressure 200 ± 15 lbf/in^2 (psi). Since one tenth of the tolerance is 3 lbf/in^2 (20.68 kPa), the converted dimension should be rounded to the nearest 10 kPa. Thus, 1378.9514 ± 103.421 35 kPa becomes 1380 ± 100 kPa.

5.2.2 *Special Cases:*

5.2.2.1 Converted values should be rounded to the minimum number of significant digits that will maintain the required accuracy, as discussed in 5.1.2. In certain cases deviation from this practice to make use of convenient or whole numbers may be feasible, in which case the word "approximate" must be used following the conversion. For example:

1⅞ in = 47.625 mm exact
47.6 mm normal rounding
47.5 mm (approx) rounded to preferred number
48 mm (approx) rounded to whole number

5.2.2.2 A quantity stated as a limit, such as "not more than" or "maximum," must be handled so that the stated limit is not violated. For example, a specimen "at least 4 in wide" requires a width of at least 101.6 mm, or at least 102 mm.

5.3 *Significant Digits:*

5.3.1 When converting integral values of units, consideration must be given to the implied or required precision of the integral value to be converted. For example, the value "4 in" may be intended to represent 4, 4.0, 4.00, 4.000, or 4.0000 in, or even greater accuracy. Obviously, the converted value must be carried to a sufficient number of digits to maintain the accuracy implied or required in the original quantity.

5.3.2 Any digit that is necessary to define the specific value or quantity is said to be significant. When measured to the nearest 1 m, a distance may be recorded as 157 m; this number has three significant digits. If the measurement had been made to the nearest 0.1 m, the distance may have been 157.4 m; this number has four significant digits.

5.3.3 Zeros may be used either to indicate a specific value, like any other digit, or to indicate the order of magnitude of a number. The 1970 United States population figure rounded to thousands was 203 185 000. The six left-hand digits of this number are significant; each *measures* a value. The three right-hand digits are zeros which merely indicate the order of *magnitude* of the number rounded to the nearest thousand. The identification of significant digits is only possible through knowledge of the circumstances. For example, the number 1000 may be rounded from 965, in which case only one zero is significant, or it may be rounded from 999.7, in which case all three zeros are significant.

5.3.4 Occasionally data required for an investigation must be drawn from a variety of sources where they have been recorded with varying degrees of refinement. Specific rules must be observed when such data are to be *added, subtracted, multiplied*, or *divided.*

5.3.4.1 The rule for addition and subtraction is that the *answer* shall contain no significant digits farther to the right than occurs in the least precise number. Consider the addition of three numbers drawn from three sources, the first of which reported data in millions, the second in thousands, and the third in units:

```
163 000 000
217 885 000
 96 432 768
-----------
477 317 768
```

The total indicates a precision that is not valid. The numbers should first be rounded to *one significant digit* farther to the right than that of the least precise number, and the sum taken as follows:

```
163 000 000
217 900 000
 96 400 000
477 300 000
```

The total is then rounded to 477 000 000 as called for by the rule. Note that if the second of the figures to be added had been 217 985 000, the rounding before addition would have produced 218 000 000, in which case the 0 following 218 would have been a significant digit.

5.3.4.2 The rule for multiplication and division is that the *product* or *quotient* shall contain no more significant digits than are contained in the number with the *fewest significant digits* used in the multiplication or division. The difference between this rule and the rule for addition and subtraction should be noted; the latter rule merely requires rounding of digits that lie to the right of the last significant digit in the least precise number. The following illustration highlights this difference:

Multiplication:
113.2 × 1.43 = 161.876, rounded to 162
Division:
113.2 ÷ 1.43 = 79.16, rounded to 79.2
Addition:
113.2 + 1.43 = 114.63, rounded to 114.6
Subtraction:
113.2 − 1.43 = 111.77, rounded to 111.8

The above product and quotient are limited to three significant digits since 1.43 contains only three significant digits. In contrast, the rounded answers in the addition and subtraction examples contain four significant digits.

5.3.4.3 Numbers used in the above illustrations have all been estimates or measurements. Numbers that are exact counts are treated as though they consist of an infinite number of significant digits. More simply stated, when a count is used in computation with a measurement the number of significant digits in the answer is the same as the number of significant digits in the measurement. If a count of 40 is multiplied by a measurement of 10.2, the product is 408. However, if 40 were an estimate accurate only to the nearest 10, and hence contained but one significant digit, the product would be 400.

5.4 *Rounding Values*[7]*:*

5.4.1 When a figure is to be rounded to fewer digits than the total number available, the procedure should be as follows:

5.4.1.1 When the first digit discarded is less than 5, the last digit retained should not be changed. For example, 3.463 25, if rounded to four digits, would be 3.463; if rounded to three digits, 3.46.

5.4.1.2 When the first digit discarded is greater than 5, or if it is a 5 followed by at least one digit other than 0, the last digit retained should be increased by one unit. For example 8.376 52, if rounded to four digits, would be 8.377; if rounded to three digits 8.38.

5.4.1.3 When the first digit discarded is exactly 5, followed only by zeros, the last digit retained should be rounded upward if it is an odd number, but no adjustment made if it is an even number. For example, 4.365, when rounded to three digits, becomes 4.36. The number 4.355 would also round to the same value, 4.36, if rounded to three digits.

5.5 *Conversion of Linear Dimensions of Interchangeable Parts*—The use of the exact relation 1 in = 25.4 mm generally produces converted values containing more decimal places than are required for the desired accuracy. It is therefore necessary to round these values suitably and at the same time maintain the degree of accuracy in the converted values compatible with that of the original values.

5.5.1 *General*—The number of decimal places given in Table 9 for rounding converted toleranced dimensions relates the degree of accuracy to the size of the tolerances specified. Two methods of using Table 9 are given: Method A, which rounds to values nearest to each limit, and Method B, which rounds to values always inside the limits.

In Method A, rounding is effected to the nearest rounded value of the limit, so that, on the average, the converted tolerances remain statistically identical with the original tolerances. The limits converted by this method, where acceptable for interchangeability, serve as a basis for inspection.

In Method B, rounding is done systematically *toward the interior* of the tolerance zone so that the converted tolerances are never larger than the original tolerances. This method must be employed when the original limits have to be respected absolutely, in particular, when components made to converted limits are to be inspected by means of original gages.

Method A—The use of this method ensures that even in the most unfavorable cases neither of the two original limits will be changed by more than 5 % of the value of the tolerance. Proceed as follows:

(*a*) Calculate the maximum and minimum limits in inches.

(*b*) Convert the corresponding two values exactly into millimetres by means of the conversion factor 1 in = 25.4 mm.

(*c*) Round the results obtained to the nearest rounded value as indicated in Table 9, depending on the original tolerance in inches, that is, on the difference between the two limits in inches.

Method B—This method must be employed when the original limits may not be violated, for instance, certain critical mating parts. In extreme cases, this method may increase the lower limit a maximum of 10 % of the tolerance and decrease the upper limit a maximum of 10 % of the tolerance.

(*a*) Proceed as in Method A step (*a*).

(*b*) Proceed as in Method A step (*b*).

(*c*) Round each limit toward the interior of the tolerance,

TABLE 9 Rounding Tolerances Inches to Millimetres

Original Tolerance, inches		Fineness of Rounding, mm
at least	less than	
0.000 04	0.000 4	0.0001
0.000 4	0.004	0.001
0.004	0.04	0.01
0.04	0.4	0.1
0.4		1

[7] Adapted from ISO R370 (7).

that is, to the next lower value for the upper limit and to the next higher value for the lower limit.[8]

Examples:

A dimension is expressed in inches as	1.950 ± 0.016
The limits are	1.934 and 1.966
Conversion of the two limits into millimetres gives	49.1236 and 49.9364
Method A—The tolerance equals 0.032 in and thus lies between 0.004 and 0.04 in (see Table 9). Rounding these values to the nearest 0.01 mm, the values in millimetres to be employed for these two limits are	49.12 and 49.94
Method B—Rounding toward the interior of the tolerance, millimetre values for these two limits are	49.13 and 49.93

This reduces the tolerance to 0.80 instead of 0.82 mm given by Method A.

5.5.2 *Special Method for Dimensions with Plus and Minus Deviations*—In order to avoid accumulation of rounding errors, the two limits of size normally are converted separately: thus, they must first be calculated if the dimension consists of a basic size and two deviations. However (except when Method B is specified) as an alternative, the basic size may be converted to the nearest rounded value and each of the deviations converted toward the interior of the tolerance. This method, which sometimes makes conversion easier, gives the same maximum guarantee of accuracy as Method A, but usually results in smaller converted tolerances.

5.5.3 *Special Methods for Limitation Imposed by Accuracy of Measurements*—If the increment of rounding for the tolerances given in Table 9 is too small for the available accuracy of measurement, limits that are acceptable for interchangeability must be determined separately for the dimensions. For example, where accuracy of measurement is limited to 0.001 mm, study shows that values converted from 1.0000 ± 0.0005 in can be rounded to 25.413 and 25.387 mm instead of 25.4127 and 25.3873 mm with little disadvantage, since neither of the two original limits is exceeded by more than 1.2 % of the tolerance.

5.5.4 *Positional Tolerance*—If the dimensioning consists solely of a positional tolerance around a point defined by a nontoleranced basic dimension, the basic dimension must be converted to the nearest rounded value and the positional variation (radius) separately converted by rounding downward.

5.5.5 *Toleranced Dimension Applied to a Nontoleranced Position Dimension*—If the toleranced dimension is located in a plane, the position of which is given by nontoleranced basic or gage dimension, such as when dimensioning certain conical surfaces, proceed as follows:

(*a*) Round the converted reference gage arbitrarily, to the nearest convenient value.

(*b*) Calculate exactly, in the converted unit of measurement, new maximum and minimum limits of the specified tolerance zone, in the new plane defined by the new basic dimension.

(*c*) Round these limits in conformity with the rules in 5.4. For example, a cone of taper 0.05 in/in has a diameter of 1.000 ± 0.002 inch in a reference plane located by the nontoleranced dimension 0.9300 in. By virtue of the taper of the cone, the limits of the tolerance zone depend on the position of the reference plane. Consequently, if the dimension 0.9300 in = 23.6220 mm is rounded to 23.600 mm (that is, a reduction of 0.022 mm), each of the two original limits, when converted exactly into millimetres, must be corrected by 0.022 × 0.05 = 0.0011 mm, in the appropriate sense, before being rounded.

5.5.6 *Consideration of Maximum and Minimum Material Condition*—The ability to assemble mating parts depends on a "go" condition at the maximum material limits of the parts. The minimum material limits, which are determined by the respective tolerances, are often not as critical from a functional standpoint. Accordingly, it may be desirable to employ a combination of Methods A and B in certain conversions by using Method B for the maximum material limits and Method A for the minimum material limits. Alternatively, it may be desirable to round automatically the converted minimum material limits outside the original limits to provide greater tolerances for manufacturing.

5.5.7 While the technique described in 5.5 provides good accuracy of conversion, it will often result in dimensions that are impractical for actual production use. For conversions intended for production, it is usually necessary to round to fewer decimal places and apply design judgment to each dimension to assure interchangeability.

5.6 *Other Units:*

5.6.1 *Temperature*—General guidance for converting tolerances from degrees Fahrenheit to kelvins or degrees Celsius is given below:

Conversion of Temperature Tolerance Requirements

Tolerance, °F	Tolerance, 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)

Normally, temperatures expressed in a whole number of degrees Fahrenheit should be converted to the nearest 0.5 kelvin (or degree Celsius). As with other quantities, the number of significant digits to retain will depend upon implied accuracy of the original dimension, for example:

100 ± 5°F; implied accuracy estimated to be 2°F.
37.7777 ± 2.7777°C rounds to 38 ± 3°C.
1000 ± 50°F; implied accuracy estimated to be 20°F.
537.7777 ± 27.7777°C rounds to 540 ± 30°C.

5.6.2 *Pressure or Stress*—As with other quantities, pressure or stress values may be converted by the principle given above. Values with an uncertainty of more than 2 % may be converted without rounding by approximate factors:

$$1\ \text{lbf/in}^2\ (1\ \text{psi}) = 7\ \text{kN/m}^2 = 7\ \text{kPa}$$

[8] If the digits to be rounded are zeros, the retained digits remain unchanged.

E 380 SELECTED CONVERSION FACTORS

To convert from	to	multiply by
atmosphere (760 mm Hg)	pascal (Pa)	$1.013\ 25 \times 10^{5}$
board foot	cubic metre (m^3)	$2.359\ 737 \times 10^{-3}$
Btu (International Table)	joule (J)	$1.055\ 056 \times 10^{3}$
Btu (International Table)/h	watt (W)	$2.930\ 711 \times 10^{-1}$
Btu (International Table)·in./s·ft²·°F (*k*, thermal conductivity)	watt per metre kelvin [W/(m·K)]	$5.192\ 204 \times 10^{2}$
calorie (International Table)	joule (J)	4.186 800*
centipoise	pascal second (Pa·s)	$1.000\ 000^{*} \times 10^{-3}$
centistokes	square metre per second (m^2/s)	$1.000\ 000^{*}\ 10^{-6}$
circular mil	square metre (m^2)	$5.067\ 075 \times 10^{-10}$
degree Fahrenheit	degree Celsius	$t°C = (t°F - 32)/1.8$
foot	metre (m)	$3.048\ 000^{*} \times 10^{-1}$
ft^2	square metre (m^2)	$9.290\ 304^{*}\ 10^{-2}$
ft^3	cubic metre (m^3)	$2.831\ 685 \times 10^{-2}$
ft·lbf	joule (J)	1.355 818
ft·lbf/min	watt (W)	$2.259\ 697 \times 10^{-2}$
ft/s^2	metre per second squared (m/s^2)	$3.048\ 000^{*} \times 10^{-1}$
gallon (U.S. liquid)	cubic metre (m^3)	$3.785\ 412 \times 10^{-3}$
horsepower (electric)	watt (W)	$7.460\ 000^{*} \times 10^{+2}$
inch	metre (m)	$2.540\ 000^{*} \times 10^{-2}$
$in.^2$	square meter (m^2)	$6.451\ 600^{*} \times 10^{-4}$
$in.^3$	cubic metre (m^3)	$1.638\ 706 \times 10^{-5}$
inch of mercury (60°F)	pascal (Pa)	$3.376\ 85 \times 10^{3}$
inch of water (60°F)	pascal (Pa)	$2.488\ 4 \times 10^{2}$
kgf/cm^2	pascal (Pa)	$9.806\ 650^{*} \times 10^{4}$
kip (1000 lbf)	newton (N)	$4.448\ 222 \times 10^{3}$
kip/$in.^2$ (ksi)	pascal (Pa)	$6.894\ 757 \times 10^{6}$
ounce (U.S. fluid)	cubic metre (m^3)	$2.957\ 353 \times 10^{-5}$
ounce-force	newton (N)	$2.780\ 139 \times 10^{-1}$
ounce (avoirdupois)	kilogram (kg)	$2.834\ 952 \times 10^{-2}$
oz (avoirdupois)/ft^2	kilogram per square metre (kg/m^2)	$3.051\ 517 \times 10^{-1}$
oz (avoirdupois)/yd^2	kilogram per square metre (kg/m^2)	$3.390\ 575 \times 10^{-2}$
oz (avoirdupois)/gal (U.S. liquid)	kilogram per cubic metre (kg/m^3)	7.489 152
pint (U.S. liquid)	cubic metre (m^3)	$4.731\ 765 \times 10^{-4}$
pound-force (lbf)	newton (N)	4.448 222
pound (lb avoirdupois)	kilogram (kg)	$4.535\ 924 \times 10^{-1}$
lbf/in^2 (psi)	pascal (Pa)	$6.894\ 757 \times 10^{3}$
lb/$in.^3$	kilogram per cubic metre (kg/m^3)	$2.767\ 990 \times 10^{4}$
lb/ft^3	kilogram per cubic metre (kg/m^3)	$1.601\ 846 \times 10$
quart (U.S. liquid)	cubic metre (m^3)	$9.463\ 529 \times 10^{-4}$
ton (short, 2000 lb)	kilogram (kg)	$9.071\ 847 \times 10^{2}$
torr (mm Hg, 0°C)	pascal (Pa)	$1.333\ 22 \times 10^{2}$
W·h	joule (J)	$3.600\ 000^{*} \times 10^{3}$
yard	metre (m)	$9.144\ 000^{*} \times 10^{-1}$
yd^2	square metre (m^2)	$8.361\ 274 \times 10^{-1}$
yd^3	cubic metre (m^3)	$7.645\ 549 \times 10^{-1}$

* Exact