The Engineering Society For Advancing Mobility Land Sea Air and Space

A Product of the Cooperative Engineering Program

# SAE J916 MAY85

# Rules for SAE Use of SI (Metric) Units

**SAE Recommended Practice**
**Revised May 1985**





**An American National Standard**

# RULES FOR SAE USE OF SI (METRIC) UNITS— SAE J916 MAY85

**SAE Recommended Practice**

Report of the Publication Policy Committee, approved June 1965, sixth revision, Publications Advisory Committee, May 1985.

*1. Introduction*—In the spring of 1969 the SAE Board of Directors issued a statement that "SAE will include SI[1] units in SAE Standards and other technical reports." Much investigation has attended the determination of units of measure, since measurement practice all over the world is to some degree in a state of transition. Engineering use of measurement units in nearly every metric country of the world, and in all of those nations adopting metric units, is changing from the noncoherent technical metric units, such as kilogram-force and calorie, to the SI units, such as newton and joule.

This document establishes the rules for the use of SI units in SAE reports, including specifications and standards. It must be remembered that a technical committee may produce its reports in any units it deems proper for the users—U. S. inch-pound, SI, or other metric. However, if the units used do not conform to the Units Approved for SAE Use (see paragraph 2), they must be followed by approved SI units in parentheses.[2]

Throughout this document, SI is intended to include recognized SI units as established by the international General Conference on Weights and Measures,[3] (CGPM) and a limited number of other units that are not formal SI units.

ϕ These other units are also included in ASTM E 380, "Standard for Metric Practice," in ANSI/IEEE 268, "Metric Practice," in "The Metric System of Measurement" issued by the Secretary of Commerce in the 26 Feb 1982 Federal Register, in NBS SP-330, "International System of Units," and in ISO 1000, the worldwide document for use by all ISO[4] committees.

This document will be updated as often as necessary to keep the use of SI units in SAE reports in harmony with the units adopted for United States and world use.

*2. Units Approved for SAE Use*—All SAE documents produced under the Board of Directors' directive to "include SI units" must utilize as applicable:

**2.1 Base Units of SI**

| Quantity | Unit (symbol) |
|---|---|
| length | —meter[5] (m) |
| mass | —kilogram (kg) |
| time | —second (s) |
| electric current | —ampere (A) |
| thermodynamic temperature | —kelvin (K) |
| amount of substance | —mole (mol) |
| luminous intensity | —candela (cd) |

**2.2 Supplementary Units of SI**

| Quantity | Unit (symbol) |
|---|---|
| plane angle | —radian (rad) |
| spherical angle | —steradian (sr) |

**2.3 Recognized Derived Units of SI with Special Names**

| Quantity | Unit (symbol) | Formula |
|---|---|---|
| absorbed dose | —gray (Gy) | J/kg |
| activity (of a radionuclide) | —becquerel (Bq) | 1/s, $s^{-1}$ |
| Celsius temperature | —degree Celsius (°C) | [6] ϕ |
| dose equivalent | —sievert[7] (Sv) | J/kg ϕ |
| electric capacitance | —farad (F) | C/V |
| electric conductance | —siemens (S) | A/V |
| electric inductance | —henry (H) | Wb/A |
| electric potential diff. | —volt (V) | W/A |
| electric resistance | —ohm (Ω) | V/A |
| energy, work | —joule (J) | N·m |
| force | —newton (N) | kg·m/s² |
| frequency | —hertz (Hz) | 1/s, $s^{-1}$ |
| illuminance | —lux (lx) | lm/m² |
| luminous flux | —lumen (lm) | cd·sr |
| magnetic flux | —weber (Wb) | V·s |
| magnetic flux density | —tesla (T) | Wb/m² |
| power | —watt (W) | J/s |
| pressure or stress | —pascal (Pa) | N/m² |
| quantity of electricity | —coulomb (C) | A·s |

See ASTM E 380 or IEEE 268 for a more complete description. ϕ

**2.4 Other Units that May be Used with SI**

| Quantity | Unit (symbol) |
|---|---|
| plane angle | —degree (°) (decimal divisions preferred) |
| time | —minute (min), hour (h), day (d), week, and year |
| mass | —metric ton (t) |
| area | —hectare (ha) |
| sound pressure level | —decibel (dB) |
| volume | —liter[4] (L)[8] ϕ |
| navigation velocity | —knot (kn)[9] ϕ |
| distance | —nautical mile (nmi)[9] ϕ |

When these units are used, they need not be followed by SI units unless it suits the purpose of the document.

The liter which the General Conference established as a special name for the cubic decimeter, is approved for SAE use, and the only prefixed use allowed is mL.

In the case of time, committees are urged to use the second and its multiples, but the units given above are permitted.

The unit metric ton (exactly 1 Mg) is in wide use but should be limited to commercial description of vehicle mass, or freight mass, and no prefix is permitted.

The unit hectare (exactly 1 hm²) is restricted to land and water area measurement.

[1] SI—The International System of Units (Système International) officially abbreviated "SI" in all languages—the modern metric system.

ϕ [2] Where standards are developed for both inch-pound and SI components, they should be cross-referenced. Such dual standards need not include metric or inch equivalents.

ϕ [3] CGPM Resolutions and Recommendations are published in NBS Special Publication 330, "The International System of Units (SI)."

ϕ [4] The International Organization for Standardization.

ϕ [5] Spelling with "re" is also used.

[6] In 1976 the International Committee on Weights and Measures (CIPM) decided that "degree Celsius" is a special name to be used in place of "kelvin" to express Celsius temperature. For formula see Section 8. ϕ

[7] Approved by CGPM in 1979. ϕ

[8] In 1979 the CGPM approved the symbol "L" for liter and it is recommended for North American use. The alternative symbol "l" will also be used during a transition period. ϕ

[9] Abbreviation, not a symbol. ϕ

The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

**2.5** Other derived units that are formed from those units and derived units indicated above are also acceptable. For example, the SI unit designation for electric field strength is V/m; however, it is also expressed in terms of base units as $kg \cdot m/(s^3 \cdot A)$ or $kg \cdot m \cdot s^{-3} \cdot A^{-1}$. Likewise, torque and bending moment (N·m) may also be expressed as $kg \cdot m^2/s^2$ or $kg \cdot m^2 \cdot s^{-2}$.

*3. Units Not Approved for Use as SI*—Gravimetric force units, such as kilogram-force, or kilogram-force per square millimeter, which have been common in some countries, must not be used in SAE reports. Similarly, calorie, bar, angstrom, and dyne are not SI units and are not to be used. However, as stated in Section 1, this restriction does not preclude use of these units where a committee considers them to be the proper units for the users of the report, and provided they are followed with approved SI units in parentheses.

*4. Multiplying Prefixes*—Table 1 lists the prefixes to be used with SI units, observing the rules given in Section 5.

*5. Rules for Use of Units*

**5.1** Requirements of this document establish the use of SI units in one of the following manners:

5.1.1 As regular units.

5.1.2 As regular units followed by other units in parentheses.

5.1.3 In parentheses following other units.

5.1.4 Under special circumstances it is permissible to deviate from these rules. See Appendix B.

**5.2** SI units must be those shown in Appendix A or their decimal multiples, except as covered in paragraph 6.2. In case of need for other units the Publications Advisory Committee of the SAE Technical Board should be consulted. If units for quantities not included in Appendix A and not clearly covered by paragraph 6.2 are required, the above committee should be contacted for guidance.

An apparent anomaly exists in the use of the joule for work (J = N·m) and the use of N·m for torque or bending moment. These are, however, entirely different units. In the former, the unit of work results from unit force moving through unit distance. In the latter, there is no implication of movement, and unit force acts at right angles to the lever arm of unit length. This would be readily seen if vectors were incorporated in the unit symbols. For these reasons, it is important to express work or energy in joules. Moment of force, torque and bending moment are expressed in newton meters, not joules.

**5.3 Use of Prefixes**

5.3.1 Use of prefixes representing 10 raised to a power that is a multiple of 3 is recommended. In the case of prefixed units that carry exponents, such as units of area and volume, this may not be practical, however, and any listed prefix may be used.

5.3.2 Compound prefixes, such as milli-micro, are never used.

5.3.3 In general, prefixes in the denominator of a compound unit should be avoided except for established usage. (Since the kilogram is a base unit of SI, use of kg in the denominator is not contrary to this guidance.)

5.3.4 When expressing a quantity by a numerical value and a unit, prefixes should preferably be chosen so that the numerical value lies between 0.1 and 1000. This is, of course, not true where certain multiples and units have been agreed to for particular use, such as kPa for pressure, or where tabular use requires the same unit in a series, even though this means exceeding the preferred range of 0.1–1000.

5.3.5 The prefix becomes a part of the symbol or name with no separation (meganewton, MN).

5.3.6 Errors in *calculations* can be minimized if all quantities are expressed in SI units, and prefixes are replaced by powers of 10.

5.3.7 With SI units of higher order, such as $m^2$ or $m^3$, the prefix is also raised to the same order; for example, 1 $mm^3$ is $(10^{-3} m)^3$ or $10^{-9} m^3$.

**TABLE 1—SI UNIT PREFIXES**

| Multiples and Submultiples | Prefixes | Symbols | Pronunciations (USA)[10] |
|---|---|---|---|
| $10^{18}$ | exa | E | . . . ex'a (*a* as in *a*bout) |
| $10^{15}$ | peta | P | . . . pet'a (*e* as in p*e*t, *a* as in *a*bout |
| $10^{12}$ | tera | T | . . . as in *terra* firma |
| $10^{9}$ | giga | G | . . . jig'a (*i* as in j*i*g, *a* as in *a*bout) |
| $10^{6}$ | mega | M | . . . as in *mega*phone |
| $10^{3}$ | kilo | k | . . . kill'oh |
| $10^{2}$ | hecto | h | . . . heck'toe |
| $10^{1}$ | deka | da | . . . deck'a (*a* as in *a*bout) |
| $10^{-1}$ | deci | d | . . . as in *deci*mal |
| $10^{-2}$ | centi | c | . . . as in *centi*pede |
| $10^{-3}$ | milli | m | . . . as in *mili*tary |
| $10^{-6}$ | micro | μ | . . . as in *micro*phone |
| $10^{-9}$ | nano | n | . . . nan'oh (*an* as in *an*t) |
| $10^{-12}$ | pico | p | . . . peek'oh |
| $10^{-15}$ | femto | f | . . . fem'toe (*fem* as in *fem*inine) |
| $10^{-18}$ | atto | a | . . . as in *anato*my |

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

**5.4 Symbols and Abbreviations**

5.4.1 Distinction—The distinction between unit symbols and unit abbreviations is not always recognized, particularly with certain U. S. inch-pound units of measurement. The symbols for some U. S. units are also abbreviations (ft, in, yd). In many cases the unit symbol and the abbreviation are not the same (such as unit symbol $ft^3$/min and abbreviation cfm; unit symbol A and abbreviation amp; unit symbol $in^3$ and abbreviation cu in). A positive distinction exists between unit symbols and unit abbreviations: the SI unit symbol designation is the same in all languages whereas abbreviations are conventional representations of words or names in a particular language; they may be different in different languages.

5.4.2 Unit Symbol Composition—Unit symbols are letters or groups of letters predominantly from the English alphabet representing the units in which physical quantities are measured (m for meter, W·h for watthour). Non-English alphabet unit symbols are (Ω) for ohm, (°) for the plane angle degree or used with the Celsius (°C) temperature scale, and (μ) for the prefix micro. All unit symbols are printed in roman (upright) type.

5.4.3 Unit Symbol Style[11]—Unit symbols are, in general, shown as lower case letters. If, however, the symbol is derived from a proper name, it or the first letter (where more than one) is an upper case letter (Hz, Wb, Pa). An exception to the above permits the upper case (L) to represent the unit liter because of the confusion that can occur between the lower case unit symbol (l) and the number one (1).

The letter style must be followed for SI unit symbols and prefixes even in applications where all other lettering is upper case (such as technical drawings). The only exception allowed is for computer and machine displays with limited character sets. For symbols for use in systems with limited character sets, refer to ANSI X3.50 or ISO 2955. The symbols for limited character sets must never be used when the available character set permits the use of the proper symbols as given herein.

5.4.4 Quantity Symbols—Quantity symbols must not be confused with unit symbols. Quantity symbols are single letters representing the magnitude of physical quantities (*I* for electric current, *e* for charge of an electron). The established symbol must always be maintained (*f*—frequency, *F*—force, *m*—mass, *M*—moment of force).

Quantity symbols are single letters of the English or Greek alphabet, and are printed in italic (slanting) type.

5.4.5 Abbreviations—Abbreviations are shortened forms of words or phrases formed in various ways that have been accepted and established (ANSI Y1.1). They are generally letters from the word being abbreviated, except where the abbreviation is taken from another language (no for number, lb for pound). Abbreviations are never to be used when a mathematical operation sign is involved, unless the abbreviation is also the symbol.

5.4.6 Symbolized Compound (Derived) Units[11]—Compound (derived) units constitute a mathematical expression. Where compound units include the solidus (/), it must not be repeated in the same expression. In complicated cases, negative powers or parentheses should be used. For example, write: $m/s^2$ or $m \cdot s^{-2}$ but not m/s/s; or write $kg \cdot m/(s^3 \cdot A)$ or $kg \cdot m \cdot s^{-3} \cdot A^{-1}$ but not $kg \cdot m/s^3/A$.

5.4.7 Plural—The form of symbols and abbreviations is the same for singular or plural (1 in, 10 in, 1 s, 27 s).

5.4.8 Periods are not used after symbols or abbreviations. The same abbreviation is used for related noun, verb, adverb, etc. (inclusion, include, inclusive are all abbreviated incl). When these rules would cause confusion, spell out the word. Words of four letters or less are not abbreviated.

5.4.9 When writing a quantity, a space should be left between the numerical value and a unit symbol—for example, write 35 mm, not 35mm. An exception occurs when the symbols for degree of plane angle or degree Celsius are used, in which case the space is omitted (25°C).

[11] Handling of Unit Names—Names of units are never capitalized except at the beginning of sentences or in titles. (Modifiers used in unit names are capitalized if proper names; for example, degree Fahrenheit.) Compound unit names are formed with a space for product and the word "per" for quotient. Prefixes become part of the word: ampere (A), milliampere (mA), ampere second (A·s), meter per second (m/s).

**TABLE 2—ABBREVIATIONS AND SYMBOLS FOR UNITS OTHER THAN SI**

| Unit Name | Symbol | Abbreviation |
|---|---|---|
| brake horsepower | | bhp |
| Brinell hardness number | | Bhn |
| British thermal unit | Btu | |
| calorie | cal | |
| candlepower | | cp |
| cubic foot per minute | $ft^3/min$ | cfm |
| cubic foot per second | $ft^3/s$ | cfs |
| cycle per minute | c/min | cpm |
| cycle per second | c/s | cps |
| cycle | c | |
| degree Fahrenheit | °F | |
| degree Rankine | °R | |
| dram | dr | |
| foot | ft | |
| footcandle | fc | |
| foot per minute | ft/min | |
| foot per second | ft/s | |
| foot pound—force | ft·lbf | |
| friction horsepower | | fhp |
| gallon | gal | |
| gallon per minute | gal/min | gpm |
| gallon per second | gal/s | gps |
| horsepower | hp | |
| inch | in | |
| inch of mercury | in Hg | |
| inch of water | in $H_2O$ | |

| Unit Name | Symbol | Abbreviation |
|---|---|---|
| inch pound—force | in·lbf | |
| kilocycle | kc | |
| kilogram—force | kgf | |
| mile | mi | |
| mile per hour | mi/h | mph |
| minute (angle) | ′ | min |
| ounce | oz | |
| ounce—force | ozf | |
| part per gallon | | ppg |
| pint | pt | |
| pound | lb | |
| poundal | pdl | |
| pound—force | lbf | |
| pound—force per square inch | $lbf/in^2$ | psi |
| pound—force per square inch absolute | | psia |
| pound—force per square inch gage | | psig |
| quart | qt | |
| revolution per minute | r/min | rpm |
| revolution per second | r/s | rps |
| Saybolt universal second | | SUS |
| second (angle) | ″ | sec |
| yard | yd | |



**5.5 Miscellaneous**

5.5.1 With nominal sizes that are not measurements but are names for items, no conversion should be made: for example, 1/4-20 UNC thread, 1 in pipe, 2 x 4 lumber.

5.5.2 The decimal marker used by SAE is the dot on the line (.) for quantities in either U. S. customary or SI units.

To facilitate the reading of numbers having five or more digits, the digits should be placed in groups of three separated by a space instead of a comma, counting both to the left and to the right of the decimal point. In the case of four digits, the spacing is optional. This style also avoids confusion caused by the use elsewhere of the comma to express the decimal marker.

For example, use:

1 532 or 1532 instead of 1,532
132 541 816 instead of 132,541,816
983 769.788 16 instead of 983,769.78816

5.5.3 Surface roughness expressed in microinches should be converted
φ to micrometers (μm); the term "micron" shall not be used.

φ 5.5.4 Linear dimensions on engineering drawings related to SAE committee documentation will customarily be given in millimeters regardless of length.

*6. General*

φ **6.1 Mass, Force, and Weight**

φ 6.1.1 The principal departure of SI from the gravimetric system of metric engineering units is the use of explicitly distinct units for mass and force. In SI, the name kilogram is restricted to the unit of mass, and the kilogram-force (from which the suffix *force* was in practice often erroneously dropped) should not be used. In its place the SI unit of force, the newton (N) is used. Likewise, the newton rather than the kilogram-force is used to form derived units which include force, for example, pressure or stress ($N/m^2$ = Pa), energy (N·m = J), and power (N·m/s = W).

6.1.2 Considerable confusion exists in the use of the term *weight* as a quantity to mean either *force* or *mass*. In commercial and everyday use, the term *weight* nearly always means mass; thus, when one speaks of a person's weight, the quantity referred to is mass. This nontechnical use of the term weight in everyday life will probably persist. In science and technology, the term *weight of a body* has usually meant the force that, if applied to the body, would give it an acceleration equal to the local acceleration of free fall. The adjective "local" in the phrase "local acceleration of free fall" has usually meant a location on the surface of the earth; in this context the "local acceleration of free fall" has the symbol *g* (commonly referred to as "acceleration of gravity"). Values of *g* differing by
φ over 0.5% at various points on the earth's surface have been observed.[12] The use of *force of gravity* (mass times acceleration of gravity) instead of *weight* with this meaning is recommended. Because of the dual use of the term weight, care should be taken to assure that the intended meaning is clear.

**6.2** Many units for rates are not shown in Appendix A, but should be derived from approved units. For example, the proper unit for mass per unit time is kg/s.

**6.3** Expressions that can be stated as a ratio of the same unit, such as 0.006 inch per inch, should be changed to a designation of a ratio such as 0.006:1. Where an expression might be shown in two different units one of which is a multiple of the other, reduce the expression to a common unit and show it as a ratio. Example: 1.50 in per ft = 0.125 ft per ft. Express as a ratio 0.125:1.

**6.4** It has been internationally recommended that pressure units themselves should not be modified to indicate whether the pressure is *absolute* (that is, above zero) or *gage* (that is, above atmospheric pressure). If, therefore, the context leaves any doubt as to which is meant, the word *pressure* must be qualified appropriately.

For example:

". . . at a gage of 200 kPa" or
". . . at an absolute pressure of 95 kPa" or
". . . reached an absolute pressure of 95 kPa," etc.

*7. Conversion Techniques*—Conversion of quantities between systems of units involves careful determination of the number of significant digits to be retained. To convert "1 quart of oil" to "0.9463529 liter of oil" is, of course, nonsense because the intended accuracy of the value does not warrant expressing the conversion in this fashion.

This section provides information to be used as a guide in the conversion of quantities specified in SAE Standards. In certain circumstances, reasons may exist for using other guidance. For example, in the case of interchangeable dimensions on engineering drawings, a more specific approach is outlined in SAE J390, Dual Dimensioning, although the methods given here will usually produce the same results.

All conversions, to be logically established, *must* depend upon an intended precision of the original quantity—either implied by a specific tolerance, or by the nature of the quantity. The first step in conversion is to establish this precision.

**7.1 Precision of a Value**—It is absolutely necessary to determine the intended precision of a value before converting.

The intended precision of a value *should* relate to the number of significant digits shown. The implied precision is plus or minus one-half unit of the last significant digit in which the value is stated. This is true because it may be assumed to have been rounded from a greater number of digits, and one-half unit of the last significant digit retained is the limit of error resulting from rounding. For example, the number 2.14 may have been rounded from any number between 2.135 and 2.145. Whether rounded or not, a quantity should always be expressed with this implication of precision in mind. For instance, 2.14 in implies a precision of ±0.005 in, since the last significant digit is in units of 0.01 in.

Two problems interfere with this, however:

(a) Quantities *may* be expressed in digits which are not intended to be significant. The dimension 1.1875 in may be a very precise one in which the digit in the fourth place is significant, or it may in some

φ [12] The value of g = 9.806 650 $m/s^2$ was confirmed in 1913 by the CGPM. This value will be used on earth whenever it is determined that the local differing value may be disregarded.

cases be an exact decimalization of a rough dimension 1$\frac{3}{16}$ in, in which case the dimension is given with too many decimal places relative to its intended precision.

(b) Quantities may be expressed omitting significant zeros. The dimension 2 in may mean "about 2 in," or it may, in fact, mean a very precise expression which should be written 2.0000 in. In the latter case, while the added zeros are not significant in establishing the value, they are very significant in expressing the proper intended precision.

Therefore, it is necessary to determine an approximate implied precision before converting. This can usually be done by using knowledge of the circumstances or information on the accuracy of measuring equipment.

If accuracy of measurement is known, this will provide a convenient lower limit to the precision of the dimension, and in some cases may be the only basis for establishing it. The implied precision should never be smaller than the accuracy of measurement.

A tolerance on a dimension will give a good indication of the intended precision, although the precision will, of course, be much smaller than the tolerance. A dimension of 1.635 ± 0.003 in obviously is intended to be quite precise, and the precision implied by the number of significant digits is correct (±0.0005 in, total 0.001 in). A dimension of 4.625 ± 0.125 in is obviously a different matter. The use of thousandths of an inch to express a tolerance of 0.25 in is probably the result of decimalization of fractions, and the expression is probably better written 4.62 ± 0.12, with an implied precision of ±0.005 (total implied precision 0.01 in). The circumstances, however, should be examined and judgment applied.

A rule of thumb often helpful for determining implied precision of a toleranced value is to assume it is one-tenth of the tolerance. Since the implied precision of the converted value should be no greater than that of the original, the total tolerance should be divided by 10, converted, and the proper significant digits retained in both the converted value and converted tolerance such that total implied precision is not reduced—that is, such that the last significant digit retained is in units no larger than one-tenth the converted total tolerance.

EXAMPLE: 200 ± 15 psi. Tolerance is 30 psi, divided by 10 is 3 psi, converted is about 20.7 kPa. The value (200 psi) converted is 1 378.9514 ± 103.421 355 kPa which should be rounded to units of 10 kPa, since 10 kPa is the largest unit smaller than one-tenth the converted tolerance. The conversion should be 1380 ± 100 kPa.

EXAMPLE: 25 ± 0.1 oz of alcohol. Tolerance is 0.2 oz, one-tenth of tolerance is 0.02 oz, converted is about 0.6 $cm^3$. The converted value (739.34 ± 2.957 $cm^3$) should be rounded to units of 0.1 $cm^3$ and becomes 739.3 ± 3.0 $cm^3$.

**7.2 Conversion Procedure**—In the sections that follow, the "total implied precision" discussed in paragraph 7.1 is referred to as "TIP."

7.2.1 First determine TIP.

7.2.2 Convert the dimension, TIP, and the tolerance if any, by the accurate conversion factor given in this document or ANSI/IEEE 268.

7.2.3 Choose the smallest number of decimals to retain, such that the last digit retained is in units equal to or smaller than the converted TIP.

7.2.4 Round off to this number of decimals by the following rules:

7.2.4.1 Where the digit next beyond the last digit to be retained is less than 5, the last digit retained should not be changed. Example: 4.46325 if rounded to three places would be 4.463.

7.2.4.2 Where the digits beyond the last digit to be retained amount to more than 5 followed by zeros, the last digit retained should be increased by one. Example: 8.37652 if rounded to three places would be 8.377.

7.2.4.3 Where the digit next beyond the last digit to be retained is exactly 5, the last digit retained, if even, is unchanged; but if odd, the last digit is increased by one. Example: 4.36500 becomes 4.36 when rounded to two places. 4.35500 also becomes 4.36 when rounded.

7.2.5 EXAMPLES

7.2.5.1 Test pressure 200 ± 15 psi
- TIP not evident in this case
- Total tolerance 30 psi, divided by 10 is 3 psi converted equals 20.68 kPa, for TIP use 10 kPA
- Units to use, 10 kPa
- 200 ± 15 psi equals 1 378.9514 ± 103.421 355 kPa, round to 1380 ± 100 kPa

7.2.5.2 A stirring rod 6 in long
- Estimate of TIP. Assume intended precision ±$\frac{1}{16}$ in, TIP = $\frac{1}{8}$ in
- Converted TIP $\frac{1}{8}$ × 25.4 = 3.17 mm
- Units to use, 1 mm
- 6 in equals 152.4 mm, round to 152 mm

7.2.5.3 50 000 psi tensile strength
- Estimate of TIP 400 psi from nature of use and precision of measuring equipment
- Converted TIP 2.8 MPa
- Units to use, 1 MPa
- 50 000 psi equals 344.737 85 MPa, round to 345 MPa

7.2.5.4 5.163 in length
- Estimate of TIP 0.001 in (significant digits judged correct)
- Converted TIP 0.0254 mm
- Units to use, 0.01 mm
- 5.163 in equals 131.1402 mm, round to 131.14 mm

7.2.5.5 12.125 in length
- Estimate of TIP 0.06 in from nature of use
- Converted TIP 1.524 mm
- Units to use 1 mm
- 12.125 in equals 307.975 mm, round to 308 mm

7.2.6 In dealing with toleranced quantities or quantities that establish limits, the rounding may be required in one direction only. When *maximum* or *minimum* are specified and judgment shows that these terms are mandatory, a maximum quantity must be rounded downward and a minimum rounded upward. The following illustrations show rounding of a dimension to two decimal places under different circumstances.

Dimension converted to 131.7625 mm
Round to two decimal places
(a) Normal dimension, untoleranced
Round to 131.76 mm (closest to original)
(b) Dimension stated as *minimum*
Round to 131.77 mm (rounded *up*)
(c) Dimension stated as *maximum*
Round to 131.76 mm (rounded *down*)

Similarly, a toleranced quantity may be rounded as in item (a). However, if critical it may be first converted to limits and each limit rounded in the appropriate fashion depending on the nature of the individual limit. For absolute maintenance of the original limits, the upper limit should be rounded down and the lower limit rounded up. (This is method B described in ASTM E 380.)

8. *Temperature Conversion*—The SI unit for thermodynamic temperature is the kelvin. The SI unit degree Celsius[13] will be used for commonly expressed temperatures.

The Celsius scale is related to the kelvin scale as follows:

One degree Celsius equals one kelvin exactly. Celsius temperature ($t_{°C}$) is related to kelvin temperature ($T_K$) as follows:

$$T_K = 273.15 + t_{°C}$$

The Celsius scale is related to the Fahrenheit scale as follows:

One degree Celsius equals $\frac{9}{5}$ of a degree Fahrenheit, exactly. Celsius temperature ($t_{°C}$) is related to Fahrenheit temperature ($t_{°F}$) as follows:

$$t_{°C} = \frac{5}{9}(t_{°F} - 32)$$

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 |
|---|---|
| ±1 | ±0.5 |
| ±2 | ±1 |
| ±5 | ±3 |
| ±10 | ±5.5 |
| ±15 | ±8.5 |
| ±20 | ±11 |
| ±25 | ±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.

[13] The term "Celsius" officially replaced "Centigrade" to eliminate confusion with French metric decimalized angular measurement (a "grad" or "grade" is 1% of a right angle, and a "centigrad" or "centigrade" is 1% of a "grad").

### 9. *Bibliography*


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[14] Available in the U.S. from American National Standards Institute (ANSI).

## APPENDIX A
Application of SI Units
(including conversion factors)

The following table illustrates recommended SI use for applications in the industries served by SAE. The particular recommendations are not mandatory, but should be followed in all SAE effort unless other use conforming to SAE J916 is strongly preferred.

*1. Arrangement*—The unit applications are arranged in alphabetical order of quantities, by principal nouns. Thus to find SI use for Surface Tension look under Tension, Surface, and for Specific Energy look under Energy, Specific.

*2. Rates and Other Derived Quantities*—It is of course not practical to list all possible applications but others such as rates can be readily derived. For example, if guidance is desired for Heat Energy per Unit Volume, looking up Energy and Volume will show the recommendation kJ/m³ (or other prefix, depending on factors discussed in paragraph 5.3).

*3. Conversion Factors*—Conversion factors are shown from Old Units to Metric Units to seven significant digits, unless the precision with which the factor is known does not warrant seven digits.

Exact conversion factors are indicated by *.

For conversion from Metric Units to Old Units, divide rather than multiply by the factor. For example, to convert 16.3 lb/yd³ to kg/m³ multiply by 0.593 276 3. The answer is 9.670 403 6 kg/m³ which should be rounded properly according to the precision of the 16.3 lb/yd³, probably to 9.7 kg/m³. To convert 9.7 kg/m³ to lb/yd³ divide by 0.593 276 3. The answer is 16.349 886 lb/yd³ which also should be rounded, probably to 16.3 lb/yd³.

## TABLE A.1

| | Quantity | Typical Application | From Old Units | To Metric Units | Multiply by |
|---|---|---|---|---|---|
| | Acceleration, angular | General | rad/s$^2$ | rad/s$^2$ | 1* |
| ϕ | Acceleration, linear | Vehicle<br>General (includes acceleration of gravity)† | (mile/h)/s<br>ft/s$^2$<br>in/s$^2$ | (km/h)/s<br>m/s$^2$<br>m/s$^2$ | 1.609 344*<br>0.304 8*<br>0.025 4* |
| | Angle, plane | Rotational calculations | r (revolution)<br>rad | r (revolution)<br>rad | 1*<br>1* |
| | | Geometric and general | ° (deg)<br>′ (min)<br>″ (sec) | °<br>° (decimalized)<br>° (decimalized) | 1*<br>1/60*<br>1/3600* |
| | Angle, solid | Illumination calculations | sr | sr | 1* |
| | Area | Cargo platforms, frontal areas, fabrics, roof and floor areas, general | in$^2$<br>ft$^2$ | m$^2$<br>m$^2$ | 0.000 645 16*<br>0.092 903 04* |
| | | Pipe, conduit | in$^2$<br>ft$^2$ | cm$^2$<br>m$^2$ | 6.451 6*<br>0.092 903 04* |
| | | Small areas, orifices | in$^2$ | mm$^2$ | 645.16* |
| | | Brake & clutch contact area, glass, radiators, agricultural | in$^2$ | cm$^2$ | 6.451 6* |
| ϕ | | Land and water areas (Small) | ft$^2$<br>yd$^2$<br>rod$^2$ | m$^2$<br>m$^2$<br>m$^2$ | 0.092 903 04*<br>0.836 127 4<br>25.292 95(d) |
| ϕ | | (Large) | acre<br>acre | m$^2$<br>ha | 4 046.873<br>0.404 687 3(d) |
| ϕ | | (Very Large) | mile$^2$ | km$^2$ | 2.589 998(d) |
| ϕ | Area per time | Field operations (agricultural) | acre/h | ha/h | 0.404 687 3(d) |
| | | Auger sweeps, silo unloader | ft$^2$/s | m$^2$/s | 0.092 903 04* |
| | Bending moment | (See Moment of force) | | | |
| | Capacitance, electric | Capacitors | μF | μF | 1* |
| | Capacity, electric | Battery rating | A·h | A·h | 1* |
| | Capacity, heat | General | Btu/°F(a) | kJ/K(b) | 1.899 101 |
| | Capacity, heat, specific | General | Btu/(lb·°F)(a) | kJ/(kg·K)(b) | 4.186 8* |
| | Capacity, volume | (See volume) | | | |
| | Coefficient of heat transfer | General | Btu/(h·ft$^2$·°F)(a) | W/(m$^2$·K)(b) | 5.678 263 |
| ϕ | Coefficient of linear expansion | Shrink fit, general | °F$^{-1}$, (1/°F) | °C$^{-1}$, (1/°C) | 1.8* |
| | Conductance, electric | General | mho | S | 1* |
| | Conductance, thermal | (See Coefficient of heat transfer) | | | |
| | Conductivity, electric | Material property | mho/ft | S/m | 3.280 840 |
| ϕ | Conductivity, thermal | General | Btu·in/(h·ft$^2$·°F)(a)<br>Btu·ft/(h·ft$^2$·°F)(a) | W/(m·K)(b)<br>W/(m·K)(b) | 0.144 227 9<br>1.730 735 |
| | Consumption, fuel | (See Efficiency, fuel) | | | |
| | Consumption, oil | Vehicle performance testing | qt/1000 miles | L/1000 km | 0.588 036 4 |
| | Consumption, specific, fuel | (See Efficiency, fuel) | | | |
| ϕ | Consumption, specific, oil | Engine testing | lb/(hp·h)<br>lb/(hp·h)<br>oz/(hp·h) | g/(kW·h)<br>g/MJ<br>g/MJ | 608.277 4<br>168.965 9<br>10.560 37 |
| | Current, electric | General | A | A | 1* |
| | Damping coefficient | | lbf·s/ft | N·s/m | 14.593 90 |

For footnotes see end of Table.
† Standard acceleration of gravity 9.806 650 m/s$^2$ exactly.

(Table continued on next page)

TABLE A.1 (CONTINUED)

| | Quantity | Typical Application | From Old Units | To Metric Units | Multiply by |
|---|---|---|---|---|---|
| | Density, current | General | A/in² <br> A/ft² | kA/m² <br> A/m² | 1.550 003 <br> 10.763 91 |
| | Density, magnetic flux | General | kilogauss | T | 0.1* |
| | Density, (mass) | Solid | lb/yd³ <br> lb/in³ <br> lb/ft³ <br> ton (short)/yd³ <br> ton (long)/yd³ | kg/m³ <br> kg/m³ <br> kg/m³ <br> kg/m³ <br> kg/m³ | 0.593 276 3 <br> 27 679.90 <br> 16.018 46 <br> 1 186.553 <br> 1 328.939 |
| | | Liquid | lb/gal | kg/L | 0.119 826 4 |
| | | Gas | lb/ft³ | kg/m³ | 16.018 46 |
| | Density of heat flow rate | Irradiance, general | Btu/(h·ft²)[a] | W/m² | 3.154 591 |
| | Diffusivity, thermal | Heat transfer | ft²/h | m²/h | 0.092 903 04* |
| | Drag | (See Force) | | | |
| ϕ | Economy, fuel or oil | (See Efficiency, fuel or oil) | | | |
| | Efficiency, fuel | Highway vehicles <br> economy <br> consumption <br> specific fuel consumption | <br> mile/gal <br> — <br> lb/(hp·h) | <br> km/L <br> L/100 km <br> g/MJ | <br> 0.425 143 7 <br> ** <br> 168.965 9 |
| | | Off-highway equipment <br> economy <br> consumption <br> specific fuel consumption <br> specific fuel consumption | <br> hp·h/gal <br> gal/h <br> lb/(hp·h) <br> lb/(hp·h) | <br> kW·h/L <br> L/h <br> g/(kW·h) <br> g/MJ | <br> 0.196 993 1 <br> 3.785 412 <br> 608.277 4 <br> 168.965 9 |
| ϕ | | Aircraft gas turbine engines <br> Thrust specific fuel consumption (Turbo-jet/fan) <br> Shaft specific fuel consumption (Turbo-shaft) | <br> lb/(lbf·h) <br> lb/(hp·h) | <br> mg/(N·s) <br> kg/(kW·h) | <br> 28.325 26 <br> 0.608 277 4 |
| ϕ | Efficiency, oil | Highway vehicles <br> economy | <br> mi/qt | <br> km/L | <br> 1.700 575 |
| | Energy, work, enthalpy, quantity of heat | Impact strength | ft·lbf | J | 1.355 818 |
| ϕ | | Heat[a] | Btu <br> kcal <br> Chu[c] | kJ <br> kJ <br> kJ | 1.055 056 <br> 4.186 8* <br> 1.899 101 |
| | | Electrical | kW·h <br> kW·h | kW·h <br> MJ | 1* <br> 3.6* |
| ϕ | | Mechanical, hydraulic, general | erg <br> ft·lbf <br> ft·pdl <br> hp·h | J <br> J <br> J <br> MJ | 0.000 000 1* <br> 1.355 818 <br> 0.042 140 11 <br> 2.684 520 |
| | Energy per area | Solar radiation | Btu/ft²[a] | MJ/m² | 0.011 356 53 |
| ϕ | Energy, specific | General[a] | cal/g[e] <br> Btu/lb | J/g <br> kJ/kg | 4.186 8* <br> 2.326* |
| | Enthalpy | (See Energy) | | | |
| | Entropy | (See Capacity, heat) | | | |
| | Entropy, specific | (See Capacity, heat specific) | | | |
| | Floor loading | (See Mass per area) | | | |
| | Flow, heat, rate | (See Power) | | | |
| | Flow, mass, rate | General | lb/min <br> lb/s | kg/min <br> kg/s | 0.453 592 4 <br> 0.453 592 4 |
| ϕ | | Dust flow | oz/min | g/min | 28.349 52 |

For footnotes see end of Table.
** Convenient conversion: 235.215 ÷ (mile/gal) = L/100 km

(Table continued on next page)

TABLE A.1 (CONTINUED)

| Quantity | Typical Application | From Old Units | To Metric Units | Multiply by |
|---|---|---|---|---|
| ϕ Flow, volume | Air, gas, general | $ft^3/s$<br>$ft^3/s$<br>$ft^3/min$ | $m^3/s$<br>$m^3/min$<br>L/min | 0.028 316 85<br>1.699 011<br>28.316 85 |
| | Liquid flow, pump capacity | gal/s<br>gal/s<br>gal/min | L/s<br>$m^3/s$<br>L/min | 3.785 412<br>0.003 785 412<br>3.785 412 |
| | Seal and packing leakage, sprayer flow | oz/s<br>oz/min | mL/s<br>mL/min | 29.573 53<br>29.573 53 |
| Flux, luminous | Light bulbs | lm | lm | 1* |
| Flux, magnetic | Coil rating | maxwell | Wb | 0.000 000 01* |
| Force, thrust, drag | Pedal, spring, belt, hand lever, general | lbf<br>ozf | N<br>N | 4.448 222<br>0.278 013 9 |
| ϕ | Drawbar, breakout, rim pull, winch line pull, general[f] | lbf<br>lbf<br>ton force (2000 lbf) | N<br>kN<br>kN | 4.448 222<br>0.004 448 222<br>8.896 444 |
| | General | pdl<br>kgf<br>dyne | N<br>N<br>N | 0.138 255 0<br>9.806 650<br>0.000 01* |
| ϕ Force loading | (See Pressure) | | | |
| Force per length | Beam loading (See also Spring rate) | lbf/ft | N/m | 14.593 90 |
| ϕ Force per mass | Tractive effort | lbf/ton (short) | N/Mg, N/t | 4.903 326 |
| Frequency | System, sound and electrical | Mc/s<br>kc/s<br>Hz, c/s | MHz<br>kHz<br>Hz | 1*<br>1*<br>1* |
| | Mechanical events, rotational (See Velocity, rotational) | | | |
| Hardness | Conventional hardness numbers, BHN, R, etc., not affected by change to SI | | | |
| Heat | (See Energy) | | | |
| Heat capacity | (See Capacity, heat) | | | |
| Heat capacity, specific | (See Capacity, heat specific) | | | |
| Heat flow rate | (See Power) | | | |
| Heat flow, density of | (See Density of heat flow) | | | |
| ϕ Heat (enthalpy), specific | General[a] | cal/g[e]<br>Btu/lb | kJ/kg<br>kJ/kg | 4.186 8*<br>2.326 |
| Heat transfer coefficient | (See Coefficient of heat transfer) | | | |
| Illuminance, illumination | General | fc | lx | 10.763 91 |
| Impact strength | (See Strength, impact) | | | |
| Impedance, mechanical | (See Damping coefficient) | | | |
| Inductance, electric | Filters and chokes, permeance | H | H | 1* |
| Intensity, luminous | Light bulbs | candlepower | cd | 1* |
| Intensity, radiant | General | W/sr | W/sr | 1* |
| Leakage | (See Flow, volume) | | | |

For footnotes see end of Table.



(Table continued on next page)

**TABLE A.1 (CONTINUED)**

| Quantity | Typical Application | From Old Units | To Metric Units | Multiply by |
|---|---|---|---|---|
| ϕ Length or Distance | Land distances, maps, odometers, aircraft range | mile (nautical)<br>mile | km<br>km | 1.852*<br>1.609 344*(d) |
| ϕ | Field size, turning circle, braking distance, cargo platforms, water depth, land levelling (cut and fill) | rod<br>yd<br>ft | m<br>m<br>m | 5.029 210(d)<br>0.914 4*<br>0.304 8* |
| | Engineering drawings, engineering part specifications, motor vehicle dimensions, general | in | mm | 25.4* |
| | Field drainage (runoff), evaporation, irrigation depth, rain and snowfall | in | cm | 2.54* |
| | Coating thickness, filter rating | mil<br>μin<br>micron | μm<br>μm<br>μm | 25.4*<br>0.025 4*<br>1* |
| | Surface texture<br>Roughness, average<br>Roughness sampling length, waviness height and spacing | μin<br>in | μm<br>mm | 0.025 4*<br>25.4* |
| | Radiation wavelengths, optical measurements, (interference) | μin | nm | 25.4* |
| ϕ Load | (See Mass)<br>(For wing loading, See Pressure) | | | |
| Luminance | Brightness | footlambert | cd/m$^2$ | 3.426 259 |
| Magnetization | Coil field strength | A/in | A/m | 39.370 08 |
| Mass | Vehicle mass (weight), axle rating, rated load, tire load, lifting capacity, tipping load, load, general | ton (long)<br>ton (short)<br>lb<br>slug | Mg, t<br>Mg, t<br>kg<br>kg | 1.016 047<br>0.907 184 7<br>0.453 592 4<br>14.593 90 |
| ϕ | Small mass | oz (avoir)<br>oz (troy)<br>grain | g<br>g<br>g | 28.349 52<br>31.103 48<br>0.064 798 91* |
| Mass per area | Fabric, surface coatings | oz/yd$^2$<br>lb/ft$^2$<br>oz/ft$^2$ | g/m$^2$<br>kg/m$^2$<br>g/m$^2$ | 33.905 75<br>4.822 428<br>305.151 7 |
| | Floor loading | lb/ft$^2$ | kg/m$^2$ | 4.882 428 |
| ϕ | Application rate, fertilizer, pesticide | lb/acre | kg/ha | 1.120 851(d) |
| ϕ | Crop yield, soil erosion | ton (short)/acre | t/ha | 2.241 702(d) |
| ϕ Mass per length or per distance | General | lb/ft<br>lb/yd | kg/m<br>kg/m | 1.488 164<br>0.496 054 7 |
| | Mass emissions | g/mi | g/km | 0.621 371 2 |
| Mass per time | Machine work capacity, harvesting, materials handling | ton (short)/h | t/h, Mg/h | 0.907 184 7 |
| Modulus, bulk | (See Pressure) | | | |
| Modulus of elasticity | General | lbf/in$^2$ | MPa | 0.006 894 757 |
| Modulus of rigidity | (See Modulus of elasticity) | | | |
| Modulus, section | General | in$^3$<br>in$^3$ | mm$^3$<br>cm$^3$ | 16 387.06<br>16.387 06 |
| Moment, bending | (See Moment of force) | | | |
| Moment of area, second | General | in$^4$<br>in$^4$ | mm$^4$<br>cm$^4$ | 416 231.4<br>41.623 14 |
| Moment of force, torque, bending moment | General, engine torque, fasteners | lbf·in<br>lbf·ft<br>kgf·cm | N·m<br>N·m<br>N·m | 0.112 984 8<br>1.355 818<br>0.098 066 5* |
| | Locks, light torque | ozf·in | mN·m | 7.061 552 |
| ϕ Moment of inertia | Flywheel, general | oz·in$^2$<br>lb·in$^2$<br>lb·ft$^2$ | g·m$^2$<br>g·m$^2$<br>kg·m$^2$ | 0.018 289 98<br>0.292 639 7<br>0.042 140 11 |

For footnotes see end of Table.

(Table continued on next page)

TABLE A.1 (CONTINUED)

| | Quantity | Typical Application | From Old Units | To Metric Units | Multiply by |
|---|---|---|---|---|---|
| | Moment of mass | Unbalance | oz·in | kg·mm | 0.720 077 8 |
| | Moment of momentum | (See Momentum, angular) | | | |
| | Moment of section | (See Moment of area, second) | | | |
| | Momentum | General | lb·ft/s | kg·m/s | 0.138 255 0 |
| | Momentum, angular | Torsional vibration | $lb \cdot ft^2/s$ | $kg \cdot m^2/s$ | 0.042 140 11 |
| | Permeability | Magnetic core properties | H/ft | H/m | 3.280 840 |
| | Permeance | (See Inductance) | | | |
| | Potential, electric | General | V | V | 1* |
| ϕ | Power | General, light bulbs | W | W | 1* |
| | | Air conditioning, heating | Btu/min[a]<br>Btu/h[a] | W<br>W | 17.584 27<br>0.293 071 1 |
| | | Motors, etc. | hp (electric) | kW | 0.746* |
| | | Engine, alternator, drawbar, power take-off, general | hp (550 ft·lbf/s) | kW | 0.745 699 9 |
| | Power per area | Solar radiation | $Btu/(ft^2 \cdot h)$[a] | $W/m^2$ | 3.154 591 |
| ϕ | Power quotient | Vehicle engine specifications | hp/ton (short) | kW/t | 0.822 324 3 |
| | | Engine Performance | lb/hp | kg/kW | 0.608 032 7 |
| ϕ | Pressure | All pressure and bulk modulus, wing loading | $lbf/in^2$<br>$lbf/in^2$ (absolute)<br>$lbf/ft^2$<br>in Hg (60°F)<br>in $H_2O$ (60°F)<br>ft $H_2O$ (60°F)<br>mm Hg (0°C) (torr)<br>$kgf/cm^2$<br>bar<br>atm (standard = 760 torr)<br>torr (mm Hg, 0°C) | kPa<br>kPa[f]<br>kPa<br>kPa<br>kPa<br>kPa<br>kPa<br>kPa<br>kPa<br>kPa<br>kPa | 6.894 757<br>6.894 757<br>0.047 880 26<br>3.376 85<br>0.248 84<br>2.986 08<br>0.133 322<br>98.066 5*<br>100*<br>101.325*<br>0.133 322 |
| ϕ | Pressure, sound, level | Acoustical measurements[h] | dB | dB | 1* |
| | Quantity of electricity | General | C | C | 1* |
| | Radiant intensity | (See Intensity, radiant) | | | |
| ϕ | Reflectance | Reflectors | cd/fc | mcd/lux | 92.903 04 |
| | Resistance, electric | General | Ω | Ω | 1* |
| | Resistivity, electric | General | Ω·ft<br>Ω·ft | Ω·m<br>Ω·cm | 0.304 8*<br>30.48* |
| | Sound pressure level | (See Pressure, sound level) | | | |
| | Speed | (See Velocity) | | | |
| | Spring rate, linear | General spring properties | lbf/in | N/mm | 0.175 126 8 |
| | Spring rate, torsional | General | lbf·ft/deg | N·m/deg | 1.355 818 |
| | Strength, field, electric | General | V/ft | V/m | 3.280 840 |
| | Strength, field, magnetic | General | oersted | A/m | 79.577 47 |
| ϕ | Strength, impact (energy absorption) | Materials testing | ft·lbf | J | 1.355 818 |
| | Stress | General | $lbf/in^2$ | MPa | 0.006 894 757 |
| | Surface tension | (See Tension, surface) | | | |

For footnotes see end of Table.



(Table continued on next page)