

**A Product of the
Cooperative Engineering Program**

SAE J916 MAY85

Rules for SAE Use of SI (Metric) Units

**SAE Recommended Practice
Revised May 1985**

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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 SI¹ 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.

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 ISO⁴ 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)

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

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.

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

⁴ The International Organization for Standardization.

⁵ Spelling with "re" is also used.

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)	°C
dose equivalent	—sievert ⁷ (Sv)	J/kg
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/s ²
frequency	—hertz (Hz)	1/s, s ⁻¹
illuminance	—lux (lx)	lm/m ²
luminous flux	—lumen (lm)	cd·sr
magnetic flux	—weber (Wb)	V·s
magnetic flux density	—tesla (T)	Wb/m ²
power	—watt (W)	J/s
pressure or stress	—pascal (Pa)	N/m ²
quantity of electricity	—coulomb (C)	A·s

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

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
navigation velocity	—knot (kn) ⁹
distance	—nautical mile (nmi) ⁹

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.

⁸ 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.

⁷ Approved by CGPM in 1979.

⁹ 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.

⁹ Abbreviation, not a symbol.

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 $\text{kg}\cdot\text{m}/(\text{s}^3\cdot\text{A})$ or $\text{kg}\cdot\text{m}\cdot\text{s}^{-3}\cdot\text{A}^{-1}$. Likewise, torque and bending moment ($\text{N}\cdot\text{m}$) may also be expressed as $\text{kg}\cdot\text{m}^2/\text{s}^2$ or $\text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}$.

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 ($J = \text{N}\cdot\text{m}$) and the use of $\text{N}\cdot\text{m}$ 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 $(10^{-3} \text{ m})^3$ or 10^{-9} m^3 .

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 watt-hour). Non-English alphabet unit symbols are (Ω) for ohm, ($^\circ$) for the plane angle degree or used with the Celsius ($^\circ\text{C}$) 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 $\text{m}\cdot\text{s}^{-2}$ but not $\text{m}/\text{s}/\text{s}$; or write $\text{kg}\cdot\text{m}/(\text{s}^3\cdot\text{A})$ or $\text{kg}\cdot\text{m}\cdot\text{s}^{-3}\cdot\text{A}^{-1}$ but not $\text{kg}\cdot\text{m}/\text{s}^3/\text{A}$.

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, 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 1—SI UNIT PREFIXES

Multiples and Submultiples	Prefixes	Symbols	Pronunciations (USA) ¹⁰
10^{18}	exa	E	... ex'a (a as in about)
10^{15}	peta	P	... pet'a (e as in pet, a as in about)
10^{12}	tera	T	... as in terra firma
10^9	giga	G	... jig'a (i as in i'g, a as in about)
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 about)
10^{-1}	deci	d	... as in decimal
10^{-2}	centi	c	... as in centipede
10^{-3}	milli	m	... as in military
10^{-6}	micro	μ	... as in micro phone
10^{-9}	nano	n	... nan'oh (an as in ant)
10^{-12}	pico	p	... peek'oh
10^{-15}	femto	f	... fem'toe (fem as in feminine)
10^{-18}	atto	a	... as in anatomy

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.

TABLE 2—ABBREVIATIONS AND SYMBOLS FOR UNITS OTHER THAN SI

Unit Name	Symbol	Abbreviation	Unit Name	Symbol	Abbreviation
brake horsepower		bhp	inch pound—force	in·lbf	
Brinell hardness number		Bhn	kilocycle	kc	
British thermal unit			kilogram—force	kgf	
calorie	Btu		mile	mi	
candlepower	cal		mile per hour	mi/h	mph
cubic foot per minute	ft ³ /min	cfm	minute (angle)	'	min
cubic foot per second	ft ³ /s	cfs	ounce	oz	
cycle per minute	c/min	cpm	ounce—force	ozf	
cycle per second	c/s	cps	part per gallon		ppg
cycle	c		pint	pt	
degree Fahrenheit	°F		pound	lb	
degree Rankine	°R		poundal	pdl	
dram	dr		pound—force	lbf	
foot	ft		pound—force per square inch	lbf/in ²	psi
footcandle	fc		pound—force per square inch absolute		psia
foot per minute	ft/min		pound—force per square inch gage		psig
foot per second	ft/s		quart	qt	
foot pound—force	ft·lbf		revolution per minute	r/min	rpm
friction horsepower		fhp	revolution per second	r/s	rps
gallon	gal		Saybolt universal second		SUS
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 ₂ O				

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 ($\text{N/m}^2 = \text{Pa}$), energy ($\text{N}\cdot\text{m} = \text{J}$), and power ($\text{N}\cdot\text{m/s} = \text{W}$).

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

ϕ ¹² The value of $g = 9.806\,650\text{ m/s}^2$ 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.

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.