

SURFACE VEHICLE STANDARD

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RULES FOR SAE USE OF SI (METRIC) UNITS

FOREWORD

In 1969, the SAE Board of Directors issued a directive that "SAE will include SI¹ units in SAE Standards and other technical reports."

In the ensuing years, the SAE metric policy evolved and implementation progressed, paced by the gradual metric transition underway in the United States and the growing international scope of SAE operations and activities.

Concurrently, SAE J916 has been updated periodically to reflect developments in the specific, formal content and in the correct, uniform usage of SI, the modern version of the metric measurement system.

For several decades the worldwide trend toward acceptance of SI has been attended by considerable deliberation and debate. Engineering use of measurement units is, to some degree, in a continuous state of transition. This occurs in virtually the entire world . . . including the original "metric countries" - as well as nations that are changing to SI from other, nonmetric, systems.

In metric countries, the changes primarily entail movement away from the former noncoherent and gravitational technical metric units, such as calorie and kilogram-force, to adopt the SI units, such as joule and newton.

The content of J916 is consistent with international and U.S. national authoritative resource documents for SI: ISO 1000; NBS SP-330; ANSI/IEEE Std. 268; ASTM E 380, and the U.S. Federal Register Notice, "Metric System of Measurement," Dec. 20, 1990.

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

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SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

TABLE OF CONTENTS

1.	SCOPE	3
2.	REFERENCES	3
2.1	Applicable Documents	3
2.2	Terminology	4
3.	SAE METRIC POLICY	5
4.	UNITS APPROVED FOR SAE USE	6
5.	UNITS NOT APPROVED FOR USE	8
6.	MULTIPLYING PREFIXES	8
7.	RULES FOR USE OF SI UNITS	9
8.	GENERAL	14
8.1	Mass, Force, Weight	14
8.2	Rates	14
8.3	Ratios	15
8.4	Pressure: Absolute and Gage	15
9.	CONVERSION TECHNIQUES	15
10.	TEMPERATURE CONVERSION	19
11.	NOTES	20
APPENDIX A	Methods for Applying SI in Tables and Graphs	21
APPENDIX B	Application of SI Units	27
APPENDIX C	Bibliography	40
RATIONALE		42

1. SCOPE:

- 1.1 This SAE Standard provides basic information on the International System of Units, abbreviated SI in all languages, and its application in engineering practice and measurement unit usage.
- 1.2 The purpose is to provide within the body of SAE's authoritative resource material, information on SI and guidance on SI's correct, uniform usage in its application to land, sea, and air design, engineering, and manufacturing practices.
- 1.3 This document establishes the rules for the use of SI units in SAE technical reports, including standards, recommended practices, information reports, as well as technical papers, publications, etc.

SAE J916 also is designated as applicable to all SAE operations, internal and external communications, products, and services for governance of SI metric practice.

- 1.4 By direction of the SAE Board of Directors (Metric Policy approved in June, 1990) "... metric (SI) units will be the only system used for expressing weights and measures ... all boards and committees will fully convert to this system by December 31, 1992 ... certain exceptions to this policy will necessarily occur when conversion to SI metric is not practical ..."
- 1.5 Throughout this document, SI is intended to include recognized SI units, as established by the International General Conference on Weights and Measures² (CGPM), and a limited number of other units that, formally, are not SI units.
- (R) SI forms the foundation of international metric standardization, but it is recognized worldwide that certain exceptions are required. For example, the degree (of plane angle), the minute, and the hour are non-SI units. It is the purpose of this standard to set forth proper SI metric practice for SAE use, and to give specific guidance concerning the acceptable use of non-SI units in SAE.

2. REFERENCES:

2.1 Applicable Documents:

(R)

The following publications form a part of this SAE standard to the extent specified herein. The latest issue of SAE Handbook or the latest SAE single copy document or version of material issued by other organizations shall apply.

- 2.1.1 U.S. Government Publications: Available from U.S. Government Printing Office, Washington, DC 20402.

NBS Special Publication 330 The International System of Units (SI) - 1986
Federal Register Notice, "Metric System of Measurement," Dec. 20, 1990

² CGPM Resolutions and Recommendations are published in NBS Special Publication 330, "The International System of Units (SI)."

2.1.2 IEEE Publications: Available from Institute of Electrical and Electronics Engineers, 345 East 47th St., New York, NY 10017.

ANSI/IEEE Std 260 Letter Symbols for SI Units and Certain Other Units of Measurement

ANSI/IEEE Std 268 Metric Practice

2.1.3 ASTM Publication: Available from American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

ASTM E 380 Standard for Metric Practice

2.1.4 ASME Publication: Available from American Society of Mechanical Engineers, 345 East 47th St., New York, NY 10017.

ANSI/ASME Y1.1-1989 Abbreviations for Use on Drawings and in Text

2.1.5 SAE Strategic Plan; March 2, 1990: Mission VI; Goal G; "Encourage and promote the use of metric weights and measures by adopting the worldwide system of SI Metrics."

2.2 Terminology:

2.2.1 To ensure consistently reliable conversion and rounding practices, a clear understanding of related nontechnical terms is helpful.

2.2.2 Certain terms used in this document 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 systemic error of an operation or process, which is seldom negligible.

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 numerical factors other than unity. The SI base units, supplementary units, and derived units form a coherent set.

HARD CONVERSION: A hard conversion is the process of changing a measurement from inch-pound units to nonequivalent metric units, which necessitates physical configuration changes of the item outside those permitted by established measurement tolerances. "Hard conversion" often is a concomitant of international standardization.

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.

METRICATION: Any act tending to increase the use of the metric system (SI), whether it be increased use of metric units or of engineering standards that are based on such units.

2.2.2 (Continued):

PRECISION (AS DISTINGUISHED FROM ACCURACY): The degree of mutual agreement between individual measurements, namely repeatability and reproducibility.

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

SI UNITS: SI denotes "Système International d'Unités"...as established in 1960, under the Treaty of the Meter, by Resolutions and Recommendations of the General Conference on Weights and Measure (Conférence General des Poids et Mesures, CGPM) and the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM) on the International System of Units.

- a. Since 1970, the International Bureau of Weights and Measures (Bureau International des Poids et Mesures, BIPM) has regularly published this authoritative information.
- b. SI units comprise the seven base SI units and coherent units derived from these base SI units using a numerical factor of one.
- c. The system is laid down in ISO 31 and ISO 1000 (ISO: International Organization for Standardization), and in NBS SP330 "The International System of Units (SI)", which is the official United States edition of the English translation of the fifth edition of "Le Système International d'Unités (SI)," the definitive publication in the French language issued in 1985 by the International Bureau of Weights and Measures (BIPM).

SOFT CONVERSION: A soft conversion is the process of changing a measurement from inch-pound units to equivalent metric units within acceptable measurement tolerances without changing the physical configuration of the item.

3. SAE METRIC POLICY: (R)

The following statement of Metric Policy was approved by the SAE Board of Directors on June 15, 1990:

SAE METRIC POLICY

Metric (SI) units will be the only system used for expressing weights and measures.

All boards and committees will fully convert to this system by December 31, 1992. The transition period is consistent with the Omnibus Trade and Competitiveness Act of 1988 and the EC92 Initiative.

3. (Continued)

It is recognized that certain exceptions to this policy will necessarily occur when conversion to SI metric is not practical (e.g.: where a conflicting world industry practice exists). These exceptions must be evaluated and approved by the operating boards on an individual basis, and reported to the Board of Directors.

4. UNITS APPROVED FOR SAE USE:

All SAE documents must utilize as applicable the metric units of SI and allowable other units given in Tables 1 through 4.

TABLE 1 - Base Units of SI

Quantity	Unit (symbol)
Length	meter ^a (m)
Mass	kilogram (kg)
Time	second (s)
Electric current	ampere (A)
Thermodynamic temperature	kelvin (K)
Amount of substance	mole (mol)
Luminous intensity	candela (cd)

^a Spelling with "re" is also used.

TABLE 2 - Supplementary Units of SI

Quantity	Unit (symbol)
Plane angle	radian (rad)
Spherical angle	steradian (sr)

TABLE 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) ^a	
Dose equivalent	sievert (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

^a 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 10.

TABLE 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) ^c , week, and year
Mass	metric ton (t)
Area	hectare (ha)
Sound pressure level	decibel (dB)
Volume	liter (L) ^a
Navigation velocity	knot (kn) ^b
distance	nautical mile (nmi) ^b

^a 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.

^b Abbreviation, not a symbol. (Status: Adopted as symbols in ANSI/IEEE STD 260; but not yet sanctioned by ISO.)

^c d is sometimes used; but not recommended for SAE Practice.



4. (Continued):

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. The only prefixed use allowed is mL. SAE preference should be to use cubic centimeter (cm^3) rather than milliliter (mL); and cubic decimeter (dm^3) rather than liter (L).

In the case of time, committees are urged to use the second and its multiples, but the units given in Tables 1 through 4 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 hm^2) is restricted to land and water area measurement.

Other derived units that are formed from the units of Tables 1 through 4 are also acceptable. Some alternative expressions for derived SI units are valid. For example, the SI unit for electric field strength is V/m; however, field strength also is 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 $\text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}$.

5. UNITS NOT APPROVED FOR USE:

Gravimetric units such as kilogram-force for force and kilogram-force per square millimeter or centimeter for pressure or stress, which have been common in some countries, must not be used in SAE practice. Similarly, calorie, bar, angstrom, and dyne are not SI units and are not approved for use.

6. MULTIPLYING PREFIXES:

Table 5 lists the prefixes to be used with SI units, observing the rules given in Section 7.

TABLE 5 - SI Unit Prefixes

Multiples and Submultiples	Prefixes	Symbols	Pronunciations (USA) ^a
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 jig, a as in about)
10^6	mega	M	...as in megaphone
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 microphone
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 fem- inine)
10^{-18}	atto	a	...as in anatomy

^a 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.

7. RULES FOR USE OF UNITS:

7.1 Requirements of this standard establish the use of SI units in SAE practice, in one of the following manners:

7.1.1 Exclusively as regular (primary) units.

- 7.1.2 As regular units followed by other units in parentheses.
- 7.1.3 Under special circumstances it is permissible to deviate from these rules. See Appendix A.
- 7.2 SI units must be those shown in Appendix B or their decimal multiples, except as covered in 6.2. In case of need for other units, the Editorial Advisory Committee of the SAE Technical Standards Board should be consulted. If units for quantities not included in Appendix B and not clearly covered by 8.2 are required, the above committee should be contacted for guidance.

An apparent anomaly exists in the use of the joule for work ($J = N \cdot m$) and the use of $N \cdot m$ 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.

7.3 Use of Prefixes:

- 7.3.1 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.
- 7.3.2 Compound prefixes, such as milli-micro, are never used.
- 7.3.3 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.)
- 7.3.4 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 and MPa for pressure, or where tabular use requires the same unit in a series, even though this means exceeding the preferred range of 0.1 to 1000.
- 7.3.5 The prefix becomes a part of the symbol or name with no separation (meganeutron, MN).
- 7.3.6 Errors in calculations can be minimized if all quantities are expressed in SI units, and prefixes are replaced by powers of 10.

7.3.7 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 .

7.4 Symbols and Abbreviations:

7.4.1 Distinction: The distinction between unit symbols and unit abbreviations (R) is not always recognized, particularly with certain U.S. inch-pound units of measure. There are, however, several distinctions between unit symbols and conventional abbreviations. Unit symbols are standardized forms, the same in all languages. They have the same form in singular and plural; they may be handled mathematically (for example, ft/s , cm^3); they are not followed by periods. Conventional abbreviations and acronyms are language-dependent (for example, cfm for cubic foot per minute), shortened presentations of words or names in a particular language. 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); see Table 6.

(R) TABLE 6 – 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 per second	kc/s	
British thermal unit	Btu		kilogram-force	kgf	
calorie	cal		mile	mi	
candlepower		cp	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	$^{\circ}\text{F}$		pound	lb	
degree Rankine	$^{\circ}\text{R}$		poundal	pd1	
dram	dr		pound-force	lbf	
foot	ft	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	$\text{ft}\cdot\text{lbf}$		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	second (angle)	"	sec
gallon per second	gal/s	gps	minute (angle)	'	min
horsepower	hp		yard	yd	yd
inch	in				
inch of mercury	inHg				
inch of water	inH ₂ O				

7.4.2 Usage: Use symbols and technical abbreviations only where necessary to save time and space and only where their meaning is unquestionably clear to the intended reader. Unit symbols are to be used in place of conventional abbreviations for units. Units used with specific numbers (for example, 3.7 m) are abbreviated or designated by symbol, except where a potential exists for misinterpretation – in which case the units should be spelled out, such as unit symbol "in" should be spelled out as "inch" or "inches."

7.4.3 Unit Symbol Composition: Unit symbols are letters or groups of letters predominantly from the Latin 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, ($^\circ$) 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. The symbol $^\circ\text{C}$ for degree Celsius is treated as an entity; the two components $^\circ$ and C are not to be separated.

7.4.4 Unit Symbol Style³: Unit symbols, in general, use 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/IEEE Std. 260. The symbols for limited character sets must not be used when the available character set permits the use of the proper symbols as given herein.

7.4.5 Quantity Symbols: Quantity symbols must not be confused with unit symbols. Quantity symbols are single letters representing 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 (Latin) or Greek alphabet, and are printed in italic (slanting) type.

³ Handling of Unit Names: Names of units are not 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).

- 7.4.6 Abbreviations: Abbreviations are shortened forms of words or phrases formed in various ways that have been approved (ANSI/ASME Y1.1 - 1989). 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.
- 7.4.7 Symbolized Compound (Derived) Units⁴: 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 m/s/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 $\text{kg}\cdot\text{m/s}^3/\text{A}$.
- 7.4.8 Plural: The form of symbols and abbreviations is the same for singular or plural (1 in, 10 in, 1 s, 27 s).
- 7.4.9 Periods are not used after symbols or abbreviations. The same abbreviation is used for related nouns, 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.
- 7.4.10 When writing a quantity, a space should be left between the numerical value and a unit symbol - for example, write 35 mm, not 35mm; write 20 °C, not 20°C.
- Exception: No space is left between numerical values and symbols for degree, minute, and second of plane angle. For example, use 45°. However in SAE Practice, the ° symbol is not used it is spelled out.

7.5 Miscellaneous:

- 7.5.1 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.
- 7.5.2 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 digit 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.

⁴ See footnote 3, pg. 11.