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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 SI[1] 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 gravitional 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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TABLE OF CONTENTS

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 Measures[2] (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

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[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'Unitès"...as established in 1960, under the Treaty of the Meter, by Resolutions and Recommendations of the General Conference on Weights and Measure (Conférénce General des Poids et Measures, CGPM) and the International Committee for Weights and Measures (Comité International des Poids et Measures, CIPM) on the International System of Units.

a. Since 1970, the International Bureau of Weights and Measures (Bureau International des Poids et Measures, 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 Systéme 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)	$kg \cdot m/s^2$
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 $kg \cdot m/(s^3 \cdot A)$ 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 $kg \cdot m^2 \cdot s^{-2}$.

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 feminine)
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·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.

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 (meganewton, 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 $(10^{-3}\ m)^3$ or $10^{-9}\ m^3$.

7.4 Symbols and Abbreviations:

7.4.1 (R) Distinction: The distinction between unit symbols and unit abbreviations 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	°F		pound	lb	
degree Rankine	°R		poundal	pdl	
dram	dr		pound-force	lbf	
foot	ft	ft	pound-force per square inch	lbf/in^2	psi
footcandle	fc				
foot per minute	ft/min		pound-force per square inch absolute		psia
foot per second	ft/s				
foot pound-force	ft·lbf		pound-force per square inch gage		psig
friction horsepower		fhp			
gallon	gal		quart	qt	
gallon per minute	gal/min	gpm	revolution per minute	r/min	rpm
gallon per second	gal/s	gps	revolution per second	r/s	rps
horsepower	hp		Saybolt universal second		SUS
inch	in		second (angle)	"	sec
inch of mercury	inHg		minute (angle)	'	min
inch of water	inH_2O		yard	yd	yd

7.4.2 (R) 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 (R) 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, (°) 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. The symbol °C for degree Celsius is treated as an entity; the two components° and C are not to be separated.

7.4.4 Unit Symbol Style[3]: 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 alway 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) Units[4]: 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 $kg \cdot m/s^3/A$.

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.

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4 See footnote 3, pg. 11.

7.5.2 (Continued):

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

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

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

8. GENERAL:

8.1 Mass, Force, and Weight:

8.1.1 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).

8.1.2 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 over 0.5% at various points on the earth's surface have been observed.[5] 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.

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

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

8.3 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.

8.4 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 to which is meant, the word pressure must be qualified appropriately.

For example:

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

9. 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, 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.

9.1 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.

9.1 (Continued):

Two problems interfere with this, however:

a. Quantities may be expressed in digits that 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 cases be an exact decimalization of a rough dimension 1-3/16 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 2.000 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 in ± 0.003 obviously is intended to be quite precise, and the precision implied by the number of significant digit is correct (±0.0005 in, total 0.001 in). A dimension of 4.625 in ± 0.125 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 psi ± 15. 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 kPa ± 103.421 355 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 kPa ± 100.

9.1 (Continued):

EXAMPLE: 25 oz ± 0.1 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 cm^3 ± 2.957) should be rounded to units of 0.1 cm^3 and becomes 739.3 cm^3 ± 3.0.

9.2 Conversion Procedure:

In the paragraphs that follow, the "total implied precision" discussed in 9.1 is referred to as "TIP".

9.2.1 First determine TIP.

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

9.2.3 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.

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

9.2.4.1 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.

9.2.4.2 Where the digits beyond the last digit is 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.

9.2.4.3 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.

9.2.5 Examples:

9.2.5.1 Test pressure 200 psi ± 15:

a. TIP not evident in this case

b. Total tolerance 30 psi, divided by 10 is 3 psi converted equals 20.68 kPa, for TIP use 10 kPa

c. Units to use, 10 kPa

d. 200 psi ± 15 equals 1 378.9514 kPa ± 103.421 355, round to 1380 kPa ± 100

9.2.5.2 A stirring rod 6 in long:

a. Estimate of TIP - Assume intended precision ±1/8 in, TIP = 1/4 in

b. Converted TIP 1/4 x 25.4 = 6.4 mm

c. Units to use, mm

d. 6 in equals 152.4 mm, round to 150 mm

9.2.5.3 50 000 psi tensile strength:

a. Estimate of TIP - 400 psi from nature of use and precision of measuring equipment

b. Converted TIP 2.8 MPa

c. Units to use, 1 MPa

d. 50 000 psi equals 344.737 85 MPa, round to 345 MPa

9.2.5.4 5.163 in length:

a. Estimate of TIP - 0.001 in (significant digits judged correct)

b. Converted TIP 0.0254 mm

c. Units to use, 0.01 mm

d. 5.163 in equals 131.1402 mm, round to 131.14 mm

9.2.5.5 12.125 in length:

a. Estimate of TIP - 0.06 in from nature of use

b. Converted TIP 1.524 mm

c. Units to use, 1 mm

d. 12.125 in equals 307.975 mm, round to 308 mm

9.2.6 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)

9.2.6 (Continued):

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.)

10. TEMPERATURE CONVERSION:

The SI unit for thermodynamic temperature is the kelvin. The SI unit degree Celsius 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:

$$T_K = 273.15 + t_{°C} \qquad \text{(Eq.1)}$$

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

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

$$t_{°C} = 5/9(t_{°F} - 32) \qquad \text{(Eq.2)}$$

General guidance for converting tolerances from degrees Fahrenheit to kelvins or degrees Celsius is given in Table 7:

TABLE 7 - Conversion of Temperature Tolerance Requirements

Tolerance, K or °C (±)	Tolerance, °F (±)
0.5	1
1	2
3	5
5.5	10
8.5	15
11	20
14	25

10. (Continued):

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:

a. 100 °F ± 5: implied accuracy estimated to be 2 °F
37.7777 °C ± 2.7777 rounds to 38 °C ± 3

b. 1000 °F ± 50: implied accuracy estimated to be 20 °F
537.7777 °C ± 27.7777 rounds to 540 °C ± 30

11. NOTES:

11.1 Marginal Indicia:

The (R) 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.

PREPARED BY THE SAE EDITORIAL ADVISORY COMMITTEE

APPENDIX A
METHODS FOR APPLYING SI IN TABLES AND GRAPHS

As covered in 7.1, SI units are required in SAE reports. To assist committees in carrying out this requirement in special circumstances, some qualifying rules are covered here.

A.1 In standards that have alternate or optional procedures based on apparatus calibrated in either U.S. inch-pound or SI units, converted values need not be included. If optional procedures or dimensions produce equally acceptable results, the options may be shown by using the word "or" rather than parentheses: for example, in a 2-in gage length metal tension test specimen, the gage length may be shown as "50 mm or 2 in."

A.2 A specific equivalent, for example 25.4 mm (1.00 in), need be inserted only the first time it occurs in each paragraph.

A.3 Special instructions cover the use of tabular material.

A.3.1 Case 1 - Limited Tabular Material: Provide SI equivalents in tables in parentheses or in separate columns (see Table A1).

TABLE A1 - Straight Wheel Grinders

H	L mm	L in	R
3/8-24 UNF-2A	28.58	1-1/8	Governed by thickness of wheel used
1/2-13 UNC-2A	44.45	1-3/4	
5/8-11 UNC-2A	53.98	2-1/8	
5/8-11 UNC-2A	79.38	3-1/8	
3/4-10 UNC-2A	82.55	3-1/4	

A.3.2 Case 2 - One or Two Large Tables: When the size of a table and limitations of space (on the printed page) make it impractical to expand the table to include SI equivalents, the table should be duplicated in U.S. inch-pound units and in SI units (see Tables A2 and A3).

TABLE A2 - Dimensions in SI Units

Chain No.	H60	H74	H75	H78	H82	H124
P (mm)	58.62	66.27	66.27	66.27	78.10	101.60
A (mm)	7.92	9.52	7.92	12.70	11.27	19.05
F (mm)	18.5	25.4	19.0	28.4	31.75	39.62
H (mm)	18.5	22.3	18.3	22.3	30.2	36.6
Proof test load (kN)						
Class M	12.50	17.80	12.50	28.50	35.60	53.40
Class P	15.60	22.20	15.60	35.60	44.50	66.80
No. of pitches per nominal 3048 mm strand	52	46	46	46	39	30
Theoretical length of nominal 3048 mm strand	3048.5	3048.2	3048.2	3048.2	3046.0	3048.0
Measuring load (N)	850	1200	850	580	2270	3600

TABLE A3 - Dimensions in U.S. Inch-Pound Units

Chain No.	H60	H74	H75	H78	H82	H124
P (in)	2.308	2.609	2.609	2.609	3.075	4.000
A (in)	0.312	0.375	0.312	0.500	0.562	0.750
F (in)	0.73	1.00	0.75	1.12	1.25	1.56
H (in)	0.75	0.88	0.72	0.88	1.19	1.44
Proof test load (lbf)						
Class M	2 800	4 000	2 800	6 400	8 000	12 000
Class P	3 500	5 000	3 500	8 000	10 000	15 000
No. of pitches per nominal 120 in strand	52	46	46	46	39	30
Theoretical length of nominal 120 in strand	120.02	120.01	120.01	120.01	119.92	120.00
Measuring load (lbf)	190	270	190	130	510	810

A.3.2.1 If Cases 1 and 2 would still result in major increase in the size of the standard, consideration must be given to other methods. SAE staff should first be consulted on techniques of arranging column spacing, etc., to accomplish addition of SI as shown in Cases 1 and 2.

A.3.2.1 (Continued):

Cases 3 and 4 are two approaches to reduce the number of pages involved in adding SI to reports with extensive tabular data. They should be used only in extreme cases since they do not accomplish the intent of SAE policy. Also, these approaches should not be considered when the users of the report are judged to need SI units for its use.

A.3.3 Case 3 - Extensive Tabular Material: When the tabulated data are extensive and the above procedures would require an impractical addition to the standard, a summary appendix may be prepared listing all of the values appearing in the tables, along with the conversion of each, as in Tables A4 through A7.

TABLE A4 - SI Equivalents: Millimeters to Inches

mm	in	mm	in	mm	in
0.38	0.015	8.89	0.350	25.07	0.987
0.51	0.020	9.52	0.375	25.40	1.000
0.71	0.028	9.73	0.383	28.65	1.128
0.97	0.038	10.95	0.431	29.92	1.178
1.12	0.044	11.10	0.437	32.26	1.270
1.27	0.050	12.37	0.487	35.81	1.410
1.42	0.056	12.70	0.500	39.90	1.571
1.63	0.064	13.72	0.540	49.86	1.963
1.80	0.071	15.55	0.612	59.84	2.356
3.63	0.143	15.88	0.625	69.82	2.749
4.85	0.191	17.78	0.700	79.81	3.142
6.07	0.239	19.05	0.750	90.02	3.544
6.65	0.262	20.07	0.790	101.35	3.990
7.26	0.286	22.22	0.875	112.52	4.430
8.48	0.334	22.58	0.889		

TABLE A5 - SI Equivalents: Square Inches to Square Centimeters

cm^2	in^2	cm^2	in^2	cm^2	in^2
0.71	0.11	2.84	0.44	6.45	1.00
1.29	0.20	3.87	0.60	8.19	1.27
2.00	0.31	5.10	0.79	10.06	1.56

TABLE A6 - SI Equivalents: Pounds per Foot to Kilograms per Meter

kg/m	lb/ft	kg/m	lb/ft	kg/m	lb/ft
0.560	0.376	2.235	1.502	4.96	3.33
0.994	0.668	3.042	2.044	6.403	4.303
1.552	1.043	3.973	2.670	7.906	5.313

TABLE A7 - SI Equivalents: Pounds-Force per Square Inch to Megapascals

MPa	psi	MPa	psi
345	50 000	550	80 000
415	60 000	620	90 000

A.3.4 (R) Case 4: In extreme cases when all the above approaches do not apply because of the size and number of tables, conversion factors may be placed in a footnote under each table, as in the example in Table A8. It should be noted that usage of inch-pound oriented material such as this is an exception to the SAE Policy and is expected to decline as the metric transition progresses with the phase-in of the SI metric oriented technical data.

TABLE A8 - Large Table With Conversion Factors as Footnotes

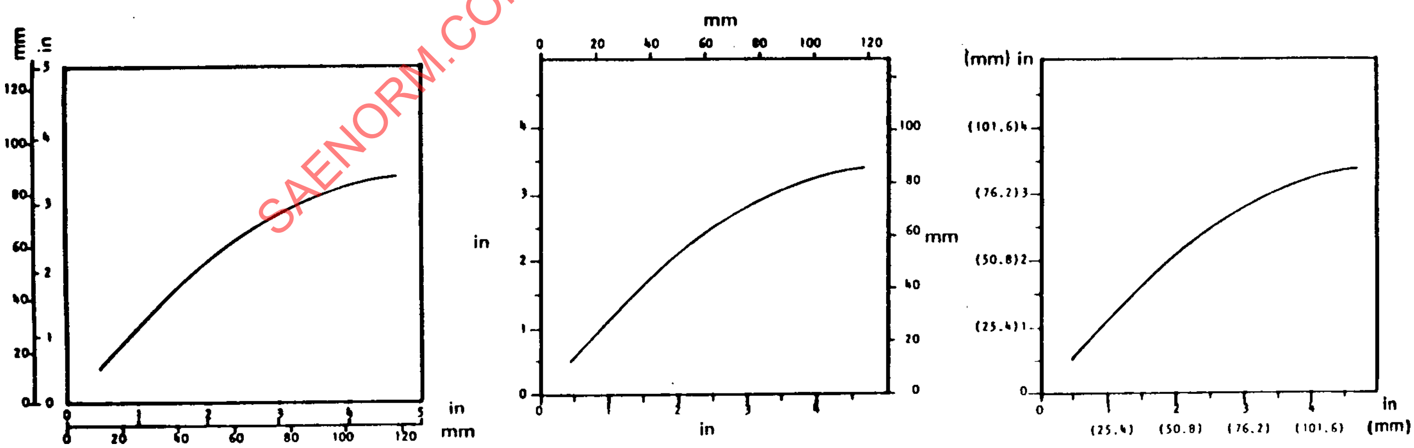
Nominal Size, in	Outside Diameter, in[a]	Wall Thickness, in[a]	Nominal Mass per ft, Plain End, lb/ft[b]	Weight Class	Schedule No.	Test Pressure,[c] Butt-Welded	Test Pressure,[c] Grade A	Test Pressure,[c] Grade B
20	20.000	0.250	52.73	—	10	—	450	500
		0.281	59.18	—	—	—	500	600
		0.312	65.60	—	—	—	550	650
		0.344	72.21	—	—	—	600	700
		0.375	78.60	STD	20	—	700	800
		0.406	84.96	—	—	—	750	850
		0.438	91.51	—	—	—	800	900
		0.469	97.83	—	—	—	850	950
		0.500	104.13	XS	30	—	900	1000
		0.594	123.11	—	40	—	1100	1200
		0.812	166.40	—	60	—	1500	1700
		1.031	208.87	—	80	—	1900	2200
		1.281	256.10	—	100	—	2300	2700
		1.500	296.37	—	120	—	2700	2800
		1.750	341.10	—	140	—	2800	2800
		1.969	379.17	—	160	—	2800	2800
24	24.000	0.250	63.41	—	10	—	400	450
		0.281	71.18	—	—	—	400	500
		0.312	78.93	—	—	—	450	550
		0.344	86.91	—	—	—	500	600
		0.375	94.62	STD	20	—	550	650
		0.406	102.31	—	—	—	600	700
		0.438	110.22	—	—	—	650	750
		0.469	117.86	—	—	—	700	825
		0.500	125.49	XS	—	—	750	900
		0.562	140.68	—	30	—	850	1000
		0.688	171.29	—	40	—	1000	1200
		0.938	231.03	—	—	—	1400	1600
		0.969	238.85	—	60	—	1500	1700
		1.219	296.58	—	90	—	1800	2100
		1.531	367.39	—	100	—	2300	2700
		1.812	429.39	—	120	—	2700	2800
		2.062	483.12	—	140	—	2800	2800
		2.344	542.14	—	160	—	2800	2800

TABLE A8 (Continued)

Nominal Size, in	Outside Diameter, in[a]	Wall Thickness, in[a]	Nominal Mass per ft, Plain End, lb/ft[b]	Weight Class	Schedule No.	Test Pressure,[c] Butt-Welded	Test Pressure,[c] Grade A	Test Pressure,[c] Grade B
26	26.000	0.250	68.75	—	—	—	50	400
		0.281	77.18	—	—	—	390	450
		0.312	85.60	—	10	—	430	500
		0.344	94.26	—	—	—	480	560
		0.375	102.63	STD	—	—	520	610
		0.406	110.98	—	—	—	560	660
		0.438	119.57	—	—	—	610	710
		0.469	127.88	—	—	—	650	760
		0.500	136.17	XS	20	—	690	810
		0.562	152.68	—	—	—	780	910

[a] 1 in = 25.4 mm
[b] 1 lb/ft = 1.49 kg/m
[c] 1 psi = 6.9 kPa

A.4. Graphs and charts may be handled in several ways depending on the circumstances. In adding SI units to a graphic presentation of data, the practice of specific addition of metric conversions to existing ordinate or abscissa values should be avoided (see Figure A1).



ACCEPTABLE PRACTICE ACCEPTABLE PRACTICE UNACCEPTABLE PRACTICE

FIGURE A1 - Graphs and Chart

APPENDIX B
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 should be followed unless other use conforming to SAE J916 is strongly preferred.

B.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.

B.2 RATES AND OTHER DERIVED QUANTITIES:

It is 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/m^3 (or other prefix, depending on factors discussed in 7.3).

B.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/yd^3 to kg/m^3 multiply by 0.593 276 3. The answer is 9.670 403 6 kg/m^3 which should be rounded properly according to the precision of the 16.3 lb/yd^3, probably to 9.7 kg/m^3. To convert 9.7 kg/m^3 to lb/yd^3 divide by 0.593 276 3. The answer is 16.349 886 lb/yd^3 which also should be rounded, probably to 16.3 lb/yd^3.

TABLE B1

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[a]
Acceleration, angular	General	rad/s^2	rad/s^2	1*
Acceleration, linear	Vehicle	(mile/h)/s	(km/h)/s	1.609 344*
	General (includes acceleration of gravity)[b]	ft/s^2	m/s^2	0.304 8*
		in/s^2	m/s^2	0.025 4*
Angle, plane	Rotational calculations	r (revolution)	r (revolution)	1*
		rad	rad	1*
	Geometric and general	° (deg)	°	1*
		' (min)	° (decimalized)	1/60*
		" (sec)	° (decimalized)	1/3600*
Angle, solid	Illumination calculations	sr	sr	1*
Area	Cargo platforms, frontal areas, fabrics, roof and floor areas, general	in^2	m^2	0.000 645 16*
		ft^2	m^2	0.092 903 04*
	Pipe, conduit	in^2	cm^2	6.451 6*
		ft^2	m^2	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*
	Land and water areas (Small)	ft^2	m^2	0.092 903 04*
		yd^2	m^2	0.836 127 4
		rod^2	m^2	25.292 95[c]
	(Large)	acre	m^2	4 046.873
		acre	ha	0.404 687 3[c]
	(Very Large)	mile^2	km^2	2.589 998[c]
Area per time	Field operations (agricultural)	acre/h	ha/h	0.404 687 3[c]
	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 charge	Battery rating	A·h	A·h	1*
Capacity, heat	General	Btu/°F(d)	kJ/K(e)	1.899 101
Capacity, heat, specific	General	Btu/(lb·°F)(d)	kJ/(kg·k)(e)	4.186 8*
Capacity, volume	(See volume)			
(R) Charge, electric	General	C	C	1*
Coefficient of heat transfer	General	Btu/(h·ft^2·°F)(d)	W/(m^2·K)(e)	5.678 263
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
Conductivity, thermal	General	Btu·in/(h·ft^2·°F)(d) Btu·ft/(h·ft^2·°F)(d)	W/(m·K)(e) W/(m·K)(e)	0.144 227 9 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)			
Consumption, specific, oil	Engine testing	lb/(hp·h) lb/(hp·h) oz/(hp·h)	g/(kW·h) g/MJ g/MJ	608.277 4 168.965 9 10.560 37
Current, electric	General	A	A	1*
Damping coefficient		lbf·s/ft	N·s/m	14.593 90
Density, current	General	A/in^2	kA/m^2	1.550 003
Density, magnetic flux	General	gauss	T	0.0001*

Footnotes at end of table.

TABLE B1 (Continued)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[(a)]
Density, (mass)	Solid	lb/yd³	kg/m³	0.593 276 3
		lb/in³	kg/m³	27 679.90
		lb/ft³	kg/m³	16.018 46
		ton (short)/yd³	kg/m³	1 136.553
		ton (long)/yd³	kg/m³	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)[(d)]	W/m²	3.154 591
Diffusivity, thermal	Heat transfer	ft²/h	m²/h	0.092 903 04*
Drag	(See Force)			
Economy, fuel or oil	(See Efficiency, fuel or oil)			
Efficiency, fuel	Highway vehicles			
	economy	mile/gal	km/L	0.425 143 7
	consumption	—	L/(100 km)	—(f)
	specific fuel consumption	lb/(hp·h)	g/MJ	168.965 9
	Off-highway equipment			
	economy	hp·h/gal	kW·h/L	0.196 993 1
	consumption	gal/h	L/h	3.785 412
	specific fuel consumption	lb/(hp·h)	g/(kW·h)	608.277 4
	specific fuel consumption	lb/(hp·h)	g/MJ	168.965 9
	Aircraft gas turbine engines			
	Thrust specific fuel consumption (turbo-jet/fan)	lb/(lbf·h)	mg/(N·s)	28.325 26
	Shaft specific fuel consumption (turbo-shaft)	lb/(hp·h)	kg/(kW·h)	0.608 277 4
Efficiency, oil	Highway vehicles			
	economy	mi/qt	km/L	1.700 575
Energy, work, enthalpy, quantity of heat	Impact strength	ft·lbf	J	1.355 818
	Heat[(d)]	Btu	kJ	1.055 056
		kcal	kJ	4.186 8*
		Chu[(g)]	kJ	1.899 101

	Electrical	kW·h	kW·h	1*
		kW·h	MJ	3.6*
	Mechanical, hydraulic, general	erg	J	0.000 000 1*
		ft·lbf	J	1.355 818
		ft·pdl	J	0.042 140 11
		hp·h	MJ	2.684 520
Energy per area	Solar radiation	Btu/ft²(d)	MJ/m²	0.011 356 53
Energy, specific	General(d)	cal/g(h)	J/g	4.186 8*
		Btu/lb	kJ/kg	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	kg/min	0.453 592 4
		lb/s	kg/s	0.453 592 4
	Dust flow	oz/min	g/min	28.349 52
Flow, volume	Air, gas, general	ft³/s	m³/s	0.028 316 85
		ft³/s	m³/min	1.699 011
		ft³/min	L/min	28.316 85
	Liquid flow, pump capacity	gal/s	L/s	3.785 412
		gal/s	m³/s	0.003 785 412
		gal/min	L/min	3.785 412
	Seal and packing leakage, sprayer flow	oz/s	mL/s	29.573 53
		oz/min	mL/min	29.573 53
Flux, luminous	Light bulbs	lm	lm	1*
Flux, magnetic	Coil rating	maxwell	Wb	0.000 000 01*

Footnotes at end of table.

TABLE B1 (Continued)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[a]
Force, thrust, drag	Pedal, spring, belt, hand lever, general	lbf	N	4.448 222
		ozf	N	0.278 013 9
	Drawbar, breakout, rim pull, winch line pull, general[i]	lbf	N	4.448 222
		lbf	kN	0.004 448 222
		ton force (2000 lbf)	kN	8.896 444
	General	pdl	N	0.138 255 0
		kgf	N	9.806 650
		dyne	N	0.000 01*
Force loading	(See Pressure)			
Force per length	Beam loading (See also Spring rate)	lbf/ft	N/m	14.593 90
Force per mass	Tractive effort	lbf/ton (short)	N/Mg, N/t	4.903 326
Frequency	System, sound and electrical	Mc/s	MHz	1*
		kc/s	kHz	1*
		Hz, c/s	Hz	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)			
Heat (enthalpy), specific	General[d]	cal/g[h]	kJ/kg	4.186 8*
		Btu/lb	kJ/kg	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)			
Length or Distance	Land distances, maps, odometers, aircraft range	mile (nautical)	km	1.852*
		mile	km	1.609 344*(c)
	Field size, turning circle, braking distance, cargo platforms, water depth, land levelling (cut and fill)	rod	m	5.029 210(c)
		yd	m	0.914 4*
		ft	m	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	µm	25.4*
		µin	µm	0.025 4*
		micron	µm	1*
	Surface texture			
	Roughness, average	µin	µm	0.025 4*
	Roughness sampling length, waviness height and spacing	in	mm	25.4*
	Radiation wavelengths, optical measurements (interference)	µin	nm	25.4*
Load	(See Mass) (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

Footnotes at end of table.