SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

TECHNICAL STANDARDS BOARD STANDARD

Submitted for recognition as an American National Standard

SAE TSB 003

REV. MAY1999

Issued 1965-06
Revised 1999-05

Superseding TSB 003 JUN92

Rules for SAE Use of SI (Metric) Units

Foreword—SI denotes The International System of Units (*Le Système International d'Unités*). SI was established in 1960, under the Treaty of the Meter, by Resolutions and Recommendations of the General Conference on Weights and Measures (*Conférence Générale 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. The abbreviation "SI" is used in all languages.

In 1969, the SAE Board of Directors issued a directive that "SAE will include SI units in SAE Standards and other technical reports." During the ensuing several decades, SAE metric policy evolved and implementation progressed. The SAE's current metric policy is, "Operating Boards shall not use any weights and measures system other than metric (SI), except when conversion is not practical, or where a conflicting world industry practice exists."

Principal driving forces for SAE metrication were: worldwide movement to metric units; enactment of United States Federal metric legislation and the resultant national metrication activity; the international trend in industry and business throughout the world, and the growing international scope of SAE. Currently, the widespread, strong support for international standards harmonization is another key motivating factor in the global metrication movement.

TSB 003 (formerly SAE J916) has been updated periodically, to reflect SAE metric policy evolution—as well as developments in the specific, formal content of SI; and in the correct, consistent usage and application of SI...which sometimes is referred to as "the modern version of the metric measurement system."

The content of TSB 003 is consistent with international and U.S. national authoritative resource documents for SI—such as: NIST SP 330; IEEE/ASTM/ANSI SI 10; the U.S. Federal Register Notice, "Metric System of Measurement"; and ISO 1000. For additional information on SI, see Section 2 of this document.

Throughout this document, SI is intended to include recognized SI units, as established by CGPM, and a limited number of other units that, formally, are not SI units. The reason is that: SI forms the foundation of international 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 document to provide guidance and further references on SI metric practice for SAE use; and, also, to give guidance concerning acceptable use of non-SI units in SAE practice.

TABLE OF CONTENTS

1. Scope

1.1 This SAE Standard provides information on the International System of Units (abbreviated SI in all languages), and its application in measurement unit usage.

1.2 The purpose is to provide information on SI and guidance on SI's correct, uniform usage in application to land, sea, and aerospace design, engineering, and manufacturing practices and technical communications.

1.3 This document and the referenced IEEE/ASTM/ANSI SI 10 Standard, establish rules for the use of SI units in SAE technical reports, including Standards, Recommended Practices, and Information Reports, as well as technical papers, publications, etc. This TSB 003 document is designated as applicable for goverance of SI metric practice in all SAE operations, internal and external communications, products, and services.

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

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. The decibel is another example.

This document provides guidance and authoritative references for acceptable use of certain non-SI units within the SAE's operations, practices, services, and products.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

In the SAE Strategic Plan, January 1, 1997, under the Technical Standards Board's implementation of the Vision "To provide world-class standards-related products and services to the global mobility industry," the SAE Vision/Ends Strategies include "H. Encourage and promote the use of metric weights and measures by adopting the system of SI Metrics."

2.1.2 ANSI PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

The SAE Metric Advisory Committee adopted (Feb. 1997) the ANSI (American National Standards Institute) American National Standard; IEEE/ASTM SI 10-1997 "Standard for Use of the International System of Units (SI): The Modern Metric System"—as the SAE's primary reference for SI. The SI 10 document is the formally designated primary American National Standard for use of the International System of Units.

2.1.3 U.S. GOVERNMENT PUBLICATIONS—Available from U.S. Government Printing Office, Washington, DC 20402.

NIST Special Publication 330—The International System of Units (SI)—1991
U.S. Federal Register Notice, Metric System of Measurement; Interpretation of the International System of Units for the United States, July 28, 1998 (see Appendix C)

2.1.4 ISO PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 1000—SI Units and Recommendations for the use of their multiples and of certain other units, 1992

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE Paper No. 850218—SI Metric for the Practicing Mechanical Engineer, S. R. Jakuba
SAE Book—Metric (SI) in Everyday Science and Engineering, Stan Jakuba, 1993
SAE & ANMC Book—Metrication for the Manager, John T. Benedict, 1992
SAE J390—Dual Dimensioning—1982

2.2.2 U.S. GOVERNMENT PUBLICATIONS—Available from U. S. Government, DOD SSP, Subscription Service Division, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094

NIST Special Publication 304—SI Chart, The Modernized Metric System, 1997
NIST Special Publication SP330—The International System of Units (SI), 1991
NIST Special Publication 811—Guide for the Use of the International System of Units, (SI), 1995
NIST Special Publication 814—Interpretation of the SI for the United States and Metric Conversion Policy for Federal Agencies, 1991
GSA (General Services Administration)—Federal Standard 376B—Preferred Metric Units for General Use by the Federal Government, 1993
U.S. Government Printing Office—Style Manual—1984
U.S. Dept. of Defense Production & Logistics Office—SD-10 Guide for Identification and Development of Metric Standards, 1990

3. Definitions—To facilitate application of SI ("The Modern Version of the Metric Measurement System"), and to ensure consistent, reliable conversion and rounding practices, an understanding of related terms is helpful. Definitions and explanations for various terms are given in Annex B1 Terminology, page 50, of the primary reference document: IEEE/ASTM SI 10-1997. Following, are definitions for some additional relevant terms.

3.1 Base Units—SI is built upon seven base units, which are regarded as independent. The base units are: meter, kilogram, second, ampere, kelvin, mole, and candela.

3.2 Capacity Rating—The capacity rating of a crane, a truck, a bridge, etc., is intended to define the mass that can be supported safely. Such a rating is expressed in a mass unit rather than a force unit, thus in kilograms or metric tons, as appropriate, rather than newtons.

3.3 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 and derived units form a coherent set.

3.4 Conversion-Hard—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.

3.5 Conversion-Soft—A soft conversion is the process of changing a measurement from inch-pound to equivalent metric units within acceptable measurement tolerances, without changing the physical configuration of the item.

3.6 Derived Units—Derived units are formed by combining base units according to the algebraic relations linking the corresponding quantities. Symbols for derived units are obtained by means of mathematical signs for multiplication, division, and the use of exponents. For example, the SI unit for speed is the meter per second (m/s or $m \cdot s^{-1}$) and that for density is kilogram per cubic meter (kg/m^3 or $kg \cdot m^{-3}$). Most derived units have only their composite names, such as meter per second for speed or velocity. Others have special names, such as newton (N), joule (J), watt (W), and pascal (Pa), given to SI units of force, energy, power, and pressure (or stress), respectively.

3.7 Inch-Pound Units—Formally, the U.S. Customary Measurement System. 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.

3.8 Load—The term "load" in mechanics means either mass, force, or pressure, depending on its use. A load that produces a vertical downward force because of the influence of gravity acting on a mass may be expressed in mass units, e.g., kilograms. A load that produces a force from anything other than the influence of gravity is expressed in force units, i.e., newtons, although the pressure unit, pascal, is used in some cases. For example, a wind, snow, or roof load may be a pressure and may be expressed in newtons per square meter (N/m^2), that is, pascals (Pa). Floor loading in a building, however, may properly be expressed in mass units, e.g., in kilograms or kilograms per square meter.

3.9 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.

3.10 SI—SI denotes The International System of Units (*Le Système International d' Unités*). SI consists of two classes of units: base units and derived units (coherent units derived from the base units.) Since 1995, the radian and steradian are deemed derived units (the supplementary units classification was eliminated). SI is defined (formally; authoritatively) in such documents as: the U.S. Federal Register, SI Notice; NIST SP330; IEEE/ASTM SI 10; ISO 1000.

3.11 Units for Mass, Weight, and Force—Mass units, such as kilogram, pound, and ounce, have often been used for units of both mass and force. This has led to serious confusion. In SI this confusion is eliminated because the unit of mass is the kilogram, and the unit of force is the newton. The kilogram-force (from which the suffix "force" in practice has often been erroneously dropped) is not used. Derived units that include force are formed using the newton.

3.12 Weight—The weight of a body in a particular reference frame is defined as the force that provides the body an acceleration equal to the local acceleration of free fall in that reference frame. Thus the SI unit of weight is the newton (N).

In commercial and everyday use, the term "weight" is often used as a synonym for mass, for which the SI unit is the kilogram. The verb "to weigh" means "to determine the mass of" or "to have a mass of." Nevertheless, in scientific and technical practice, the term "weight" should not be used to mean mass.

3.13 Work, Heat, Energy—The joule (N·m) is work done when the point of application of a force of one newton is displaced a distance of one meter in the direction of the force. The SI unit of energy is the joule, which is equal to newton meter or watt second. The kilowatt hour is accepted as a unit of electrical energy only.

4. SAE Metric Policy

4.1 Statement—The following statement of Metric Policy was approved by the SAE Board of Directors on March 4, 1993:

4.1.1 SAE METRIC POLICY—Operating Boards shall not use any weights and measures system other than metric (SI), except when conversion is not practical, or where a conflicting world industry practice exists..."

5. Measurement Units Approved for SAE Use

5.1 As noted above, SAE has endorsed and adopted as its primary SI Reference, the ANSI/IEEE/ASTM SI 10-1997 document, which is the primary American National Standard for SI. SAE Reports and other documents must utilize, as applicable, the metric units of SI and other allowable units given in the SI 10-1997 Standard and in Appendix C.

5.2 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).

5.3 In regard to time, committees should use the second and its multiples, except where minutes or hours units are warranted.

EXAMPLE—km/h for velocity.

5.4 Additional examples of approved non-SI units.

5.4.1 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.

5.4.2 The unit hectare (exactly 1 h m^2) is restricted to land and water area measurement.

5.4.3 In acoustics, the bel is retained as a unit for measuring the loudness of sounds, in its prefixed form, decibel (dB).

5.5 Some 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 $kg{\cdot}m^2{\cdot}s^{-2}$

6. Units Not Approved for Use

6.1 Gravimetric units such as kilogram-force for force and kilogram-force per square millimeter or centimeter for pressure or stress, which have been commonly used in some countries, must not be used in SAE metric practice. Similarly: calorie, bar, angstrom, and dyne are not SI units, and are not approved for general use. Numerous examples of units that are not to be used, are listed in Table 8, pp.10-11, of the primary referenced Standard, IEEE/ASTM SI 10.

7. Rules for Use of SI Units

7.1 Requirements of this document 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 Appendices B and C, or their decimal multiples or units derived from approved units. For example: use kg/s for mass per unit time. In case of need for other units, the Metric Advisory Committee of the SAE Technical Standards Board should be consulted. If units for quantities not included in Appendix B 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 and other energy in joules. Moment of force, torque and bending moment are expressed in newton meters, not joules.

7.3 Symbols and Abbreviations

7.3.1 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 1.

7.3.2 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."

TABLE 1—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	mile	
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		
footcandle	fc		square inch	lbf/in^2	psi
foot per minute	ft/min		pound-force per		
foot per second	ft/s		square inch absolute		psia
foot pound-force	ft · lbf		pound-force per		
friction horsepower		fhp	square inch gage		psig
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

7.3.3 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 watt hour). 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.

7.3.4 UNIT SYMBOL STYLE[1]—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.

1. 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).

7.3.5 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.

7.3.6 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.

7.3.7 SYMBOLIZED COMPOUND (DERIVED) UNITS[1]—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 $kg \cdot m/s^3/A$.

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

7.3.9 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.

7.3.10 When writing a quantity, a space is 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. Example: 45°. However in SAE Practice, the ° symbol is not used for plane angle. The word degree is spelled out.

7.4 Mass, Force, and Weight

7.4.1 The principal departure of SI from the gravimetric system of metric engineering units is the use of 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 that include force, for example, pressure or stress (N/m^2 = Pa), energy (N·m = J), and power (N·m/s = W).

7.4.2 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 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" 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 0.57 at various points on the earth's surface have been observed.[2] In a technical context, the use of force of gravity (mass times acceleration of gravity), instead of weight with this meaning is recommended. Because the term weight is ambiguous, care should be taken to assure that the intended meaning is clear.

1. See footnote 1.
2. The standard value of g = 9.806 650 m/s^2 was adopted in 1913 by the CGPM. This value is used on earth whenever it is determined that the local differing value may be disregarded.

7.4.3 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; (see 7.2).

7.5 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 degree is related to the kelvin degree as follows:

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

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

The Celsius degree is related to the Fahrenheit degree 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:

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

General guidance for converting tolerances from degrees Fahrenheit to kelvins or degrees Celsius is given in Table 2.

TABLE 2—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

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

7.6 Miscellaneous

7.6.1 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.

7.6.2 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.

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

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

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

7.6.5 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.

7.6.6 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.

8. Notes

8.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

8.2 Historical Note—When tracing the background/history of TSB 003, it is necessary to know... that ... this SAE Standard was renumbered in 1992. At that time, it was put into a new class of TSB (Technical Standards Board) documents and designated TSB 003. As stated in the Foreword (paragraph 4), prior to 1992, it was SAE J916. The SAE J916 number was used from the inception of *Rules for SAE Use of SI (Metric) Units*, in 1965, through various revisions, including the 1991 version of J916.

PREPARED BY THE SAE METRIC ADVISORY COMMITTEE

APPENDIX A

METHODS FOR APPLYING SI IN TABLES AND GRAPHS

Preface—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—FASTENERS FOR GRINDERS

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

A.3.2.1 If Cases 1 and 2 would still result in major increase in the size of the standard document, 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.

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, A5, A6, and A7.

A.3.4 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 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.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).

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

TABLE A8—LARGE TABLE WITH CONVERSION FACTORS AS FOOTNOTES

Nominal Size, in	Outside Diameter, in[1]	Wall Thickness, in[1]	Nominal Mass per ft. Plain End, lb/ft[2]	Weight Class	Schedule No.	Test Pressure,[3] Butt-Welded	Test Pressure,[3] Grade A	Test Pressure,[3] 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
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

1. 1 in = 25.4 mm
2. 1 lb/ft = 1.49 kg/m
3. 1 psi = 6.9 kPa

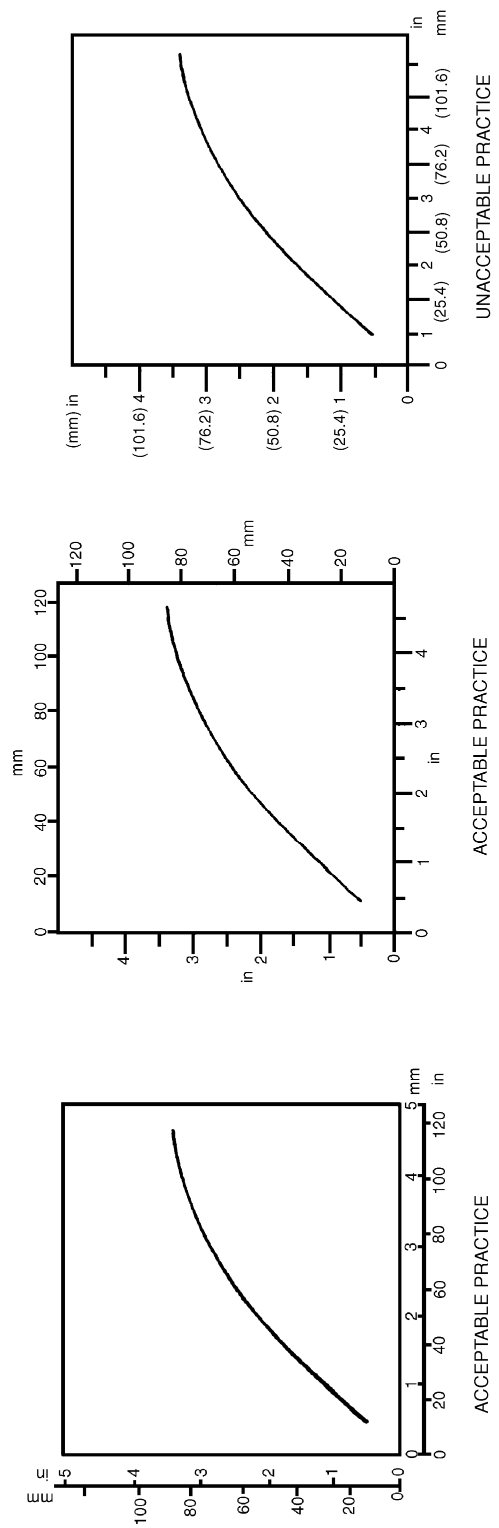

FIGURE A1—GRAPHS AND CHARTS

APPENDIX B

APPLICATION OF SI UNITS (INCLUDING CONVERSION FACTORS)

***Preface*—**The following table illustrates recommended SI use for applications in the industries and technical disciplines served by SAE. The particular recommendations should be followed unless other use conforming to TSB 003 is strongly preferred for well-founded reasons.

***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 guidelines for the use of prefixes).

***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. The answer is 9.6659 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. The answer is 16.357504 lb/yd^3, which would be rounded to 16.3 lb/yd^3, the precision of the 9.7 kg/m^3.

TABLE B1—APPLICATION OF SI UNITS

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by(1)
Acceleration, angular	General	rad/s^2	rad/s^2	1*
Acceleration, linear	Vehicle	(mi/h)/s	(km/h)/s	1.609 344*
	General (includes acceleration	ft/s^2	m/s^2	0.304 8*
	of gravity(2)	in/s^2	m/s^2	0.025 4*
Acoustical Measurement (see Pressure, Sound, Level)				
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,	in^2	m^2	0.000 645 16*
	general	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
	(Large)	acre	m^2	4 046.873
		acre	ha	0.404 687 3(3)
	(Very Large)	mi^2	km^2	2.589 998(3)
Area per time	Field operations (agricultural)	acre/h	ha/h	0.404 687 3(3)
	Auger sweeps, silo unloader	ft^2/s	m^2/s	0.092 903 04*
Bending moment	(See Moment of force)			

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[1]
Capacitance, electric	Capacitors	μF	μF	1*
Capacity, electric charge	Battery rating	A·h	A·h	1*
Capacity, heat	General	Btu/°F[4]	kJ/K[5]	1.899 101
Capacity, heat, specific	General	Btu/(lb·°F)[4]	kJ/(kg·K)[5]	4.186 8*
Capacity, volume	(See volume)			
Charge, electric	General	C	C	1*
Coefficient of heat transfer	General	Btu/(h·ft^2·°F)[4]	W/(m^2·K)[5]	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)[4] Btu·ft/(h·ft^2·°F)[4]	W/(m·K)[5] W/(m·K)[5]	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	A/mm^2	1.550 003
Density, magnetic flux	General	gauss	T	0.0001*

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[1]
Density, (mass)	Solid	lb/yd^3	kg/m^3	0.593 276 3
		lb/in^3	kg/m^3	27 679.90
		lb/ft^3	kg/m^3	16.018 46
		$ton (short)/yd^3$	kg/m^3	1 186.553
		$ton (long)/yd^3$	kg/m^3	1 328.939
	Liquid	lb/gal	kg/L	0.119 826 4
	Gas	lb/ft^3	kg/m^3	16.018 46
Density of heat flow rate	Irradiance, general	$Btu/(h·ft^2)$[4]	W/m^2	3.154 591
Diffusivity, thermal	Heat transfer	ft^2/h	m^2/h	0.092 903 04*
Drag	(See Force)			
Economy, fuel or oil	(See Efficiency, fuel or oil)			
Efficiency, fuel[6]	Highway vehicles			
	economy	mi/gal	km/L	0.425 143 7
	consumption	—	L/(100 km)	—[7]
	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[6]	Highway vehicles economy	mi/qt	km/L	1.700 575
Energy, work, enthalpy, quantity of heat	Heat[4]	Btu	kJ	1.055 056
		kcal	kJ	4.186 8*
	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

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[1]
	Impact Strength	ft·lbf	J	1.355 818
Energy per area	Solar radiation	Btu/ft^2[4]	MJ/m^2	0.011 356 53
Energy, specific	General[4]	cal/g[8]	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	ft^3/s	m^3/s	0.028 316 85
		ft^3/s	m^3/min	1.699 011
		ft^3/min	L/min	28.316 85
	Liquid flow, pump capacity	gal/s	L/s	3.785 412
		gal/s	m^3/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	1m	1m	1*
Flux, magnetic	Coil rating	maxwell	Wb	0.000 000 01*
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[9]	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*

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[1]
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*
		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[4]	cal/g[7]	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, Mass, or volume)			
Length or Distance	Land distances, maps, odometers, aircraft range	mile (nautical)	km	1.852*
		mile	km	1.609 344*[3]

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[1]
	Field size, turning circle, braking distance, cargo platforms, water depth, land leveling (cut and fill)	rod	m	5.029 210[3]
		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	foot lambert	cd/m^2	3.426 259
Magnetization	Coil field strength	A/in	A/m	39.370 08
Mass	Vehicle mass (weight), axle rating, rated load, tire load, lifting capacity, tipping load, load, general	ton (long)	Mg, t	1.016 047
		ton (short)	Mg, t	0.907 184 7
		lb	kg	0.453 592 4
		slug	kg	14.593 90
	Small mass	oz (avoir)	g	28.349 52
		oz (troy)	g	31.103 48
		grain	g	0.064 798 91*
Mass per area	Fabric, surface coatings	oz/yd^2	g/m^2	33.905 75
		lb/ft^2	kg/m^2	4.822 428
		oz/ft^2	g/m^2	305.151 7
	Floor loading	lb/ft^2	kg/m^2	4.882 428

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by(1)
	Application rate, fertilizer, pesticide	lb/acre	kg/ha	1.120 851(3)
	Crop yield, soil erosion	ton (short)/acre	t/ha	2.241 702(3)
Mass per length or per distance	General	lb/ft	kg/m	1.488 164
		lb/yd	kg/m	0.496 054 7
	Mass emissions	g/mi	g/km	0.621 371 2
Mass per time	Machine work capacity, harvesting, materials handling	ton (short)/h	t/h, Mg/h	0.907 184 7
Modulus, bulk	(See Pressure)			
Modulus of elasticity	General	lbf/in^2	MPa	0.006 894 757
Modulus of rigidity	(See Modulus of elasticity)			
Modulus, section	General	in^3	mm^3	16 387.06
		in^3	cm^3	16.387 06
Moment, bending	(See Moment of force)			
Moment of area, second	General	in^4	mm^4	416 231.4
		in^4	cm^4	41.623 14
Moment of force, torque bending moment	General, engine torque, fasteners	lbf·in	N·m	0.112 984 8
		lbf·ft	N·m	1.355 818
		kgf·cm	N·m	0.098 066 5*
	Locks, light torque	ozf·in	mN·m	7.061 552
Moment of inertia	Flywheel, general	$oz{\cdot}in^2$	$g{\cdot}m^2$	0.018 289 98
		$lb{\cdot}in^2$	$g{\cdot}m^2$	0.292 639 7
		$lb{\cdot}ft^2$	$kg{\cdot}m^2$	0.042 140 11
Moment of mass	Unbalance	oz·in	kg·mm	0.720 077 8
Moment of momentum	(See Momentum, angular)			
Moment of section	(See Moment of area, second)			
Momentum	General	lb·ft/s	kg·m/s	0.138 255 0
Momentum, angular	Torsional vibration	$lb{\cdot}ft^2/s$	$kg{\cdot}m^2/s$	0.042 140 11
Permeance	(See Inductance)			

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[1]
Permeability	Magnetic core properties	H/ft	H/m	3.280 840
Potential, electric	General	V	V	1*
Power	General, light bulbs	W	W	1*
	Air conditioning, heating	Btu/min[4]	W	17.584 27
		Btu/h[4]	W	0.293 071 1
	Motors, etc.	hp (electric)	kW	0.746*
	Engine, alternator, drawbar, power take-off, general	hp (550 ft·lbf/s)	kW	0.745 699 9
Power per area	Solar radiation	Btu/(ft^2·h)[4]	W/m^2	3.154 591
Power quotient	Vehicle engine specifications	hp/ton (short)	kW/t	0.822 324 3
	Engine Performance	lb/hp	kg/kW	0.608 032 7
Pressure	All pressure and bulk modulus, wing loading	lbf/in^2	kPa	6.894 757
		lbf/in^2 (absolute)	kPa[8]	6.894 757
		lbf/ft^2	kPa	0.047 880 26
		inHg (60 °F)	kPa	3.376 85
		inH_2O (60 °F)	kPa	0.248 84
		ftH_2O (60 °F)	kPa	2.986 08
		mmHg (0 °C) (torr)	kPa	0.133 322
		kgf/cm^2	kPa	98.066 5*
		bar	kPa	100*
		atm (standard = 760 torr)	kPa	101.325*
		torr (mmHg, 0 °C)	kPa	0.133 322
Pressure, sound, level	Acoustical measurements[10]	decibel	dB	1*
Radiant intensity	(See Intensity, radiant)			
Reflectance	Reflectors	cd/fc	mcd/lux	92.903 04
Resistance, electric	General	Ω	Ω	1*
Resistivity, electric	General	Ω·ft	Ω·m	0.304 8*
		Ω·ft	Ω·cm	30.48*
Sound pressure level	(See Pressure, sound level)			
Speed	(See Velocity)			
Spring rate, linear	General spring properties	lbf/in	N/mm	0.175 126 8

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by(1)
Spring rate, torsional	General	lbf·ft/deg	N·m/*	1.355 818
Strength, field, electric	General	V/ft	V/m	3.280 840
Strength, field, magnetic	General	oersted	A/m	79.577 47
Strength, impact (energy absorption)	Materials testing	ft·lbf	J	1.355 818
Stress	General	lbf/in^2	MPa	0.006 894 757
Surface tension	(See Tension, surface)			
Surface texture	Roughness measurement	μm	μm	0.0254*
Temperature Scale	General use	°F	°C	$t_{°C} = (t_{°F} - 32)/1.8$*
	Absolute temperature, thermodynamics, gas cycles	°R	K	$T_K = T_{°R}/1.8$*
Temperature interval	General use	°F	K(5)	1 K = 1 °C = 1.8 °F*
Tension, surface	General	lbf/in	mN/m	175 126.8
		dyne/cm	mN/m	1*
Thrust	(See Force)			
Time	General	s	s	1*
		h	h	1*
		min	min	1*
Torque	(See Moment of Force)			
Toughness, Fracture	Metal properties	$ksi\sqrt{in}$	$MPa \cdot m^{1/2}$	1.098 843
Vacuum	(See Pressure)			
Velocity, angular	(See Velocity, rotational)			
Velocity, linear	Vehicle	mi/h	km/h	1.609 344*
		knot (international)	km/h	1.852*
	General	ft/s	m/s	0.304 8*
		ft/min	m/min	0.304 8*
		in/s	mm/s	25.4*

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by(1)
Velocity, rotational	Mechanical events (rotational) and general	rad/s	rad/s	1*
		r/s	r/s, r·s^{-1}	1*
		r/min	r/min, r·min^{-1}	1*
		rpm	rad/s	0.104 72
Viscosity, dynamic	General liquids	centipoise	mPa·s	1*
Viscosity, kinematic	General liquids	centistokes	mm^2/s	1*
Volume	Truck body, shipping or freight, bucket capacity, grain bins and tanks, general	yd^3	m^3	0.764 554 9
		ft^3	m^3	0.028 316 85
		bushel	m^3	0.035 239 07
		peck (U.S. day)	m^3	0.008 097 68
		in^3	m^3	0.000 016 387 06
	Automobile luggage capacity	ft^3	dm^3 or L	28.316 85
	Gas pump displacement, air compressor, small gaseous, air reservoir	in^3	cm^3	16.387 06
	Engine displacement			
	large engines	in^3	L or dm^3	0.016 387 06
	small engines	in^3	cm^3	16.387 06
	Liquid—fuel, lubricant, etc.	gal	L or dm^3	3.785 412
		pt	L or dm^3	0.473 176 5
		qt	L or dm^3	0.946 352 9
	Small liquid	oz	mL	29.573 53
	Irrigation, reservoir	acre·ft	m^3	1 233.489(3)
			dam^3	1.233 489(3)
Volume per area	Application rate, pesticide	gal/acre	L/ha	9.353 958(3)
Weight	May mean either mass or force - (see 7.4)			

Footnotes at end of table.

TABLE B1—APPLICATION OF SI UNITS (CONTINUED)

Quantity	Typical Application	From Old Units	To Metric Units	Multiply by[1]
Work	(See Energy)			
Young's modulus	(See Modulus of elasticity)			

Footnotes

1. An * indicates an exact conversion factor.
2. Standard acceleration of gravity 9.806 65 m/s^2 exactly.
3. Official use in surveys and cartography involves the U.S. survey foot, which is longer than the international foot by two parts per million. The factors used in this standard for acre, acre foot, U.S. statute mile, and rod are based on the U.S. survey foot. Factors for all other old length-related units are based on the international foot.
4. Conversion of Btu and calorie are based on the International Table Btu and calorie
5. In these expressions K indicates temperature interval. Therefore K may be replaced with °C if desired without changing the value or affecting the conversion factor. For example: kJ/(kg·K) = kJ/(kg· °C).
6. Convenient conversion: 235.215 ÷ (mile/gal) = L/100 km. (NOTE—Conversion based on the U.S. Gallon.)
7. Not to be confused with kcal/g. The kcal is often called "calorie" in the nutritional field.
8. Lift capacity ratings for cranes, hoists, and related components such as rope, cables, chains, etc., should be rated in mass units. Those items such as winches, which can be used for pulling as well as lifting, shall be rated in both force and mass units.
9. When frequency weighting is specified, show weighting in parentheses following the symbol. For example: dB (A).
10. Refer to 7.6.6 for treatment of absolute pressure.

APPENDIX C

FEDERAL REGISTER NOTICE, JULY 28, 1998
METRIC SYSTEM OF MEASUREMENT: INTERPRETATION OF THE INTERNATIONAL SYSTEM OF UNITS FOR THE UNITED STATES

Preface—Appendix C is an SAE adaptation of Federal Register Notice, July 28, 1998—Metric System of Measurement: Interpretation of the International System of Units for the United States, which consists only of reformatting the FEDERAL REGISTER NOTICE of JULY 28, 1998 into SAEs format.

C.1 FEDERAL REGISTER NOTICE, July 28, 1998—Metric System of Measurement: Interpretation of the International System of Units for the United States—DEPARTMENT OF COMMERCE

National Institute of Standards and Technology

[Docket No. 980430113-8113-01]

Metric System of Measurement: Interpretation of the International System of Units for the United States

AGENCY: National Institute of Standards and Technology, Commerce.

ACTION: Notice.

C.1.1 Summary—This notice restates the intepretation of the International System of Units (SI) for the United States by the Department of Commerce. This interpretation was last published by the Department of Commerce in the **Federal Register** on December 20, 1990 (55 FR 52242-52245). Since the publication of that notice, the international bodies that are responsible for the SI have made some changes to it. It has therefore become necessary to set forth a new interpretation of the SI for the United States that reflects these changes.

C.1.2 For Futher Information Contact—For information regarding the International System of Units, contact Dr. Barry N. Taylor, Building 225, Room B161, National Institute of Standards and Technology, Gaithersburg, MD 20899-0001, telephone number (301) 975-4220. For information regarding the Federal Government's efforts to coordinate the transition of the United States to the International System of Units, contact Mr. James B. McCracken, Metric Program, Building 820, Room 306, National Institute of Standards and Technology, Gaithersburg, MD 20899-0001, telephone number (301) 975-3690, email: metric_prg@nist.gov.

C.1.3 Supplementary Information—Section 5164 of Public Law 100–418, the Omnibus Trade and Competitiveness Act of 1988, amended Public Law 94–168, the Metric Conversion Act of 1975. In particular, section 3 of the Metric Conversion Act (codified as amended 15 U.S.C. 205b) reads as follows:

"Sec. 3. It is therefore the declared policy of the United States—

1. to designate the metric system of measurement as the preferred system of weights and measures for United States trade and commerce;
2. to require that each Federal agency, by a date certain and to the extent economically feasible by the end of the fiscal year 1992, use the metric system of measurement in its procurements, grants, and other business related activities, except to the extent that such use is impractical or is likely to cause significant inefficiencies or loss of markets to United States firms, such as when foreign competitors are producing competing products in non-metric units;
3. to seek out ways to increase understanding of the metric system of measurement through educational information and guidance and in Government publications; and
4. to permit the continued use of traditional systems of weights and measures in nonbusiness activities."

In the Metric Conversion Act of 1975, the 'metric system of measurement' is defined as the International System of Units as established in 1960 by the General Conference of Weights and Measures (abbreviated CGPM after the *French Conférence Général des Poids et Mesures*) and interpreted or modified for the United States by the Secretary of Commerce (15 U.S.C. 205c). The Secretary has delegated this authority to the Director of the National Institute of Standards and Technology. In implementation of this authority, tables and associated text were published in the **Federal Register** of December 20, 1990 (55 FR 52242-52245), setting forth the interpretation for the United States of the International System of Units (abbreviated SI in all languages after the French *Systéme International d'Unités*).

The CGPM is an intergovernmental organization established by the Meter Convention (*Convention du Métre*), which was signed by the United States and 16 other countries in Paris in 1875 (nearly 50 countries are now members of the Convention). One of the responsibilities of the CGPM is to ensure that the SI reflects the latest advances in science and tehcnology. Since the publication of the 1990 **Federal Register** notice, the CGPM has made two significant changes to the SI. These are (1) the addition of four new SI prefixes to form decimal multiples and submultiples of SI units; and (2) the elimination of the class of supplementary units (the radian and the steradian) as a separate class in the SI. Further, the International Committee for Weights and Measures (abbreviated CIPM after the French *Comité International des Poids et Mesures*), which comes under the authority of the CGPM, has made some new recommendations regarding units not part of the SI that may be used with the SI. It is therefore necessary to issue new tables and associated text that reflect these changes and which set forth a new interpretation of the SI for the United States. Thus this **Federal Register** notice supersedes the previous interpretation published in the **Federal Register** on December 20, 1990 (55 FR 52242-52245).

C.1.4 Classes of SI Units—There are now only two classes of units in the International System of Units: *base units* and *derived units*. The units of these two classes form a *coherent* set of units and are designated by the name "SI units." Here, the term coherent is used to mean a unit system where all derived units are obtained from the base units by the rules of multiplication and division with no numerical factor other than the number 1 ever occurring in the expressions for the derived units in terms of the base units. The SI also includes *prefixes* to form decimal multiples and submultiples of SI units. Because units formed with SI prefixes are not coherent with SI units, the units so formed are designated by their complete name "decimal multiples and submultiples of SI units" in order to make a distinction between them and the coherent set of SI units proper. The SI units and their decimal multiples and submultiples together are often called "units of the SI."

C.1.5 SI Base Units—The SI is founded on seven SI *base units* for seven *base quantities* assumed to be mutually independent. These units and quantities are given in Table C1.

TABLE C1—SI BASE UNITS

Base Quantity	SI Derived Unit Name	SI Derived Unit Symbol
length	meter	m
mass(1)	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

1. "Weight" in common parlance is often used to mean mass.

C.1.6 SI Derived Units—Other quantities, called *derived quantities*, are defined in terms of these seven base quantities through a system of quantity equations. Si *derived units* for these derived quantities are obtained from this system of equations and the seven SI base units in a coherent manner, which means, in keeping with the above discussion of the term coherent, that they are formed as products of powers (both positive and negative) of the SI base units corresponding to the base quantities concerned without numerical factors. Table C2 gives some examples of SI derived units.

TABLE C2—EXAMPLES OF SI DERIVED UNITS

Derived Quantity	SI Derived Unit Name	SI Derived Unit Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	reciprocal meter	m^{-1}
mass density (density)	kilogram per cubic meter	kg/m^3
specific volume	cubic meter per kilogram	m^3/kg
current density	ampere per square meter	A/m^2
magnetic field strength	ampere per meter	A/m
amount-of-substance concentration (concentration)	mole per cubic meter	mol/m^3
luminance	candela per square meter	cd/m^2
mass fraction	kilogram per kilogram, which may be represented by the number 1	kg/kg = 1

C.1.7 Quantities of Dimension 1—The last entry of Table C2, mass fraction, is an example of certain derived quantities that are defined as the ratio of two mutually comparable quantities, that is, two quantities of the same kind. Since the coherent SI derived unit of such a derived quantity is the ratio of two identical SI units, that unit may also be expressed by the number one, symbol 1. Such quantities are called *quantities of dimension 1*, or *dimensionless quantities*, and the SI unit of all such quantities is the number 1. Examples of other derived quantities of dimension 1, and thus with a coherent SI derived unit that may be expressed by the number 1, are relative permeability, dynamic friction factor, refractive index, characteristic numbers such as the Mach number, and numbers that represent a count, such as a number of molecules. However, the number 1 is generally not explicitly shown in the expression for the value of a quantity of dimension 1. For example, the value of the refractive index of a given medium is expressed as $n = 1.51$ rather than as $n = 1.51 \times 1$. In a few cases a special name and symbol are given to the number 1 to aid understanding. The radian, unit symbol rad, and steradian, unit symbol sr, which are given in Table C3 and are discussed in connection with Table C4, are two such examples.

C.1.8 SI Derived Units With Special Names and Symbols—For ease of understanding and convenience, 21 SI derived units have been given special names and symbols. These are listed in Table C3, where it should be noted that the last three units of Table C3, the becquerel, unit symbol Bq, the gray, unit symbol Gy, and the sievert, unit symbol Sv, were specifically introduced by the CGPM with a view to safeguarding human health.

TABLE C3—SI DERIVED UNITS WITH SPECIAL NAMES AND SYMBOLS

Derived Quantity	SI Derived Unit Special Name	SI Derived Unit Special Symbol	SI Derived Unit Expression in Terms of Other SI Units	SI Derived Unit Expression in Terms of SI Base Units
plane angle	radian	rad		$m \cdot m^{-1} = 1$
solid angle	steradian	sr		$m^2 \cdot m^{-2} = 1$
frequency	hertz	Hz		s^{-1}
force	newton	N		$m\ kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	N · m	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
electric charge, quantity of electricity	coulomb	C		s·A
electric potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
magnetic flux	weber	Wb	V · s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
Celsius temperature	degree Celsius	°C		K
luminous flux	lumen	lm	cd · sr	$m^2 \cdot m^{-2} \cdot cd = cd$
illuminance	lux	lx	lm/m^2	$m^2 \cdot m^{-4} \cdot cd = m^{-2} \cdot cd$
activity (of a radionuclide)	becquerel	Bq		s^{-1}
absorbed dose, specific energy (imparted), kerma	gray	Gy	J/kg	$m^2 \cdot s^{-2}$
dose equivalent, ambient dose equivalent, directional dose equivalent, personal dose equivalent, equivalent dose	sievert	SV	J/kg	$m^2 \cdot s^{-2}$

C.1.9 Degree Celsius—The derived unit in Table C3 with special name degree Celsius and special symbol °C deserves comment. Because of the way temperature scales used to be defined, it remains common practice to express a thermodynamic temperature, symbol T, in terms of its difference from the reference temperature T_0 = 273.15 K, the ice point. This temperature difference is called Celsius temperature, symbol t, and is defined by the quantity equation $t = T - T_0$. The unit of Celsius temperature is the degree Celsius, symbol °C. The numerical value of a Celsius temperature t expressed in degrees Celsius is given by

$$\frac{t}{°C} = \frac{T}{K} - 273.15 \qquad \text{(Eq. C1)}$$

It follows from the definition of t that the degree Celsius is equal in magnitude to the kelvin, which in turn implies that the numerical value of a given temperature difference or temperature interval whose value is expressed in the unit degree Celsius (°C) is equal to the numerical value of the same difference or interval when its value is expressed in the unit kelvin (K). Thus temperature differences or temperature intervals may be expressed in either the degree Celsius or the kelvin using the same numerical value. For example, the Celsius temperature difference Δt and the thermodynamic temperature difference ΔT between the melting point of gallium and the triple point of water may be written as Δt = 29.7546 °C = ΔT = 29.7546 K. (Note that the centigrade temperature scale is obsolete; the unit name degree centigrade should no longer be used.)

C.1.10 Use of SI Derived Units With Special Names and Symbols—The special names and symbols of the 21 SI derived units with special names and symbols given in Table C3 may themselves be included in the names and symbols of other SI derived units. This use is shown in Table C4. All of the SI derived units in Table C4, like those in Table C3, have been obtained from the SI base units in the same coherent manner discussed above.

TABLE C4—EXAMPLES OF SI DERIVED UNITS WHOSE NAMES AND SYMBOLS INCLUDE SI DERIVED UNITS WITH SPECIAL NAMES AND SYMBOLS

Derived Quantity	SI Derived Unit Name	SI Derived Unit Symbol	SI Derived Unit Expression in Terms of SI Base Units
dynamic viscosity	pascal second	Pa · s	$m^{-1}\cdot kg\cdot s^{-1}$
moment of force	newton meter	N · m	$m^2\cdot kg\cdot s^{-2}$
surface tension	newton per meter	N/m	$kg\cdot s^{-2}$
angular velocity	radian per second	rad/s	$m\cdot m^{-1}\cdot s^{-1} = s^{-1}$
angular acceleration	radian per second squared	rad/s^2	$m\cdot m^{-1}\cdot s^{-2} = s^{-2}$
heat flux density, irradiance	watt per square meter	W/m^2	$kg\cdot s^{-3}$
heat capacity, entropy	joule per kelvin	J/K	$m^2\cdot kg\cdot s^{-2}\cdot K^{-1}$
specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg·K)	$m^2\cdot s^{-2}\cdot K^{-1}$
specific energy	joule per kilogram	J/kg	$m^2\cdot s^{-2}$
thermal conductivity	watt per meter kelvin	W/(m·K)	$m\cdot kg\cdot s^{-3}\cdot K^{-1}$
energy density	joule per cubic meter	J/m^3	$m^{-1}\cdot kg\cdot s^{-2}$
electric field strength	volt per meter	V/m	$m\cdot kg\cdot s^{-3}\cdot A^{-1}$
electric charge density	coulomb per cubic meter	C/m^3	$m^{-3}\cdot s\cdot A$
electric flux density	coulomb per square meter	C/m^2	$m^{-2}\cdot s\cdot A$
permittivity	farad per meter	F/m	$m^{-3}\cdot kg^{-1}\cdot s^4\cdot A^2$
permeability	henry per meter	H/m	$m\cdot kg\cdot s^{-2}\cdot A^{-2}$
molar energy	joule per mole	J/mol	$m^2\cdot kg\cdot s^{-2}\cdot mol^{-1}$
molar entropy, molar heat capacity	joule per mole kelvin	J/(mol·K)	$m^2\cdot kg\cdot s^{-2}\cdot K^{-1}\cdot mol^{-1}$
exposure (x and γ rays)	coulomb per kilogram	C/kg	$kg^{-1}\cdot s\cdot A$
absorbed dose rate	gray per second	Gy/s	$m^2\cdot s^{-3}$
radiant intensity	watt per steradian	W/sr	$m^4\cdot m^{-2}\cdot kg\cdot s^{-3} = m^2\cdot kg\cdot s^{-3}$
radiance	watt per square meter steradian	$W/(m^2\cdot sr)$	$m^2\cdot m^{-2}\, kg\cdot s^{-3} = kg\cdot s^{-3}$

C.1.11 Radian and Steradian—As indicated in Table C3, the radian, unit symbol rad, and steradian, unit symbol sr, are the special names and symbols for the derived units of plane angle and solid angle, respectively. These units may be used or not in expressions for derived units as is convenient in order to distinguish between derived quantities that are not of the same kind but are of the same dimension (that is, derived quantities whose units when expressed in SI base units are the same). Table C4 includes some examples of derived units that use the radian and steradian.

C.1.12 SI Prefixes—Table C5 gives the 20 SI prefixes used to form decimal multiples and submultiples of SI units. It is important to note that the kilogram is the only SI unit with a prefix as part of its name and symbol. Because multiple prefixes may not be used, in the case of the kilogram the prefix names of Table C5 are used with the unit name "gram" and the prefix symbols are used with the unit symbol "g." With this exception, any SI prefix may be used with any SI unit, including the degree Celsius and its symbol °C.

TABLE C5—SI PREFIXES

Factor	Name	Symbol	Factor	Name	Symbol
$10^{24} = (10^3)^8$	yotta	Y	10^{-1}	deci	d
$10^{21} = (10^3)^7$	zetta	Z	10^{-2}	centi	c
$10^{18} = (10^3)^6$	exa	E	$10^{-3} = (10^3)^{-1}$	milli	m
$10^{15} = (10^3)^5$	peta	P	$10^{-6} = (10^3)^{-2}$	micro	µ
$10^{12} = (10^3)^4$	tera	T	$10^{-9} = (10^3)^{-3}$	nano	n
$10^{9} = (10^3)^3$	giga	G	$10^{-12} = (10^3)^{-4}$	pico	p
$10^{6} = (10^3)^2$	mega	M	$10^{-15} = (10^3)^{-5}$	femto	f
$10^{3} = (10^3)^1$	kilo	k	$10^{-18} = (10^3)^{-6}$	atto	a
10^{2}	hecto	h	$10^{-21} = (10^3)^{-7}$	zepto	z
10^{1}	deka	da	$10^{-24} = (10^3)^{-8}$	yocto	y

Because the SI prefixes strictly represent powers of 10, it is inappropriate to use them to represent powers of 2. Thus 1 kbit = 10^3 bit = 1000 bit and *not* 2^{10} = 1024 bit, where 1 kbit is one kilobit.

C.1.13 Units Outside the SI—Certain units are not part of the International System of Units, that is, they are outside the SI, but are important and widely used. Consistent with the recommendations of the CIPM, the units in this category that are accepted for use in the United States with the SI are given in Tables C6 and C7.

TABLE C6—UNITS OUTSIDE THE SI THAT ARE ACCEPTED FOR USE WITH THE SI

Name		Symbol	Value in SI Units
minute	time	min	1 min = 60 s
hour	time	h	1 h = 60 min = 3600 s
day	time	d	1 d = 24 h = 86 400 s
degree	plane angle	°	1° = (π/180) rad
minute	plane angle	′	1′ = (1/60)° = (π/10 800) rad
second	plane angle	″	1″ = (1/60)′ = (π/648 000) rad
liter		L	1 L = 1 $dm^3 = 10^{-3}\ m^3$
metric ton		t	1 t = 10^3 kg
neper		Np	1 Np = 1
bel		B	1 B = (1/2) ln 10 NP(1)

1. Although the neper is coherent with SI units and is accepted by the CIPM, it has not been adopted by the CGPM and is thus not an SI unit.

TABLE C7—UNITS OUTSIDE THE SI THAT ARE ACCEPTED FOR USE WITH THE SI, BUT WHOSE VALUES IN SI UNITS ARE OBTAINED EXPERIMENTALLY

Name	Symbol	Value in SI Units[(1)]
electronvolt[(2)]	eV	1 eV = 1.602 177 33(49) x 10^{-19} J
unified atomic mass unit[(3)]	u	1 u = 1.660 540 2(10) x 10^{-27} kg
astronomical unit[(4)]	ua	1 ua = 1.495 978 70(30) x 10^{11} m

1. The combined standard uncertainty (that is, estimated standard deviation) of the last two figures is shown in parentheses.
2. The electronvolt is the kinetic energy acquired by an electron in passing through a potential difference of 1 V in vacuum.
3. The unified atomic mass unit is equal to 1/12 of the mass of an unbound atom of the nuclide ^{12}C at rest and in its ground state.
4. The astronomical unit is a unit of length approximately equal to the mean Earth-Sun distance. Its value is such that, when used to describe the motion of bodies in the solar system, the heliocentric gravitation constant is $(0.017\ 202\ 098\ 95)^2\ ua^3 \cdot d^{-2}$.

C.1.14 Liter and Metric Ton—The units liter and metric ton in Table C6 deserve comment. The liter and its symbol l were adopted by the CIPM in 1879. The alternative symbol for the liter, L, was adopted by the CGPM in 1979 in order to avoid the risk of confusion between the letter l and the number 1. Thus, although *both* l and L are internationally accepted symbols for the liter, to avoid this risk the preferred symbol for use in the United States is L. Neither a lowercase script letter l nor an uppercase script letter l are approved symbols for the liter. With regard to the metric ton, this is the name to be used in the United States for the unit with symbol t and defined according to 1 t = 10^3 kg. (The name "metric ton" is also used in some other English speaking countries, but the name "tonne" is used in many countries.)

C.1.15 Other Units Outside the SI—Other units outside the SI that are currently accepted for use with the SI in the United States are given in Table C8. These units, which are subject to future review by the NIST Director on behalf of the Secretary of Commerce, should be defined in relation to the SI in every document in which they are used; their continued use is not encouraged. The CIPM currently accepts the use of all of the units given in Table C8 with the SI except for the curie, roentgen, rad, and rem. Because of the continued wide use of these units in the United States, especially in regulatory documents dealing with health and safety, this interpretation of the SI for the United States accepts their use with the SI. Nevertheless, use of the corresponding SI units is encouraged whenever possible, with values given in terms of the older units in parentheses if necessary.

TABLE C8—OTHER UNITS OUTSIDE THE SI THAT ARE CURRENTLY ACCEPTED FOR USE WITH THE SI, SUBJECT TO FUTURE REVIEW

Name	Symbol	Value in SI Units
nautical mile		1 nautical mile = 1852 m
knot		1 nautical mile per hour = (1852/3600) m/s
arc[(1)]	a	1 a = 1 dam^2 = 10^2 m^2
hectare[(1)]	ha	1 ha = 1 hm^2 = 10^4 m^2
bar	bar	1 bar = 0.1 MPa = 1 kPa = 1000 hPa = 10^5 Pa
ångstrõm	Å	1 Å = 0.1 nm = 10^{-10} m
barn	b	1 b = 100 fm^2 = 10^{-28} m^2
curie	Ci	1 Ci = 3.7 x 10^{10} Bq
roentgen	R	1 R = 2.58 x 10^{-4} C/kg
rad	rad[(2)]	1 rad = 1 cGy = 10^{-2} Gy
rem	rem	1 rem = 1 cSv = 10^{-2} Sv

1. This unit and its symbol are used to express areas of land.
2. When there is risk of confusion with the symbol for the radian, rd may be used as the symbol for rad.

C.1.16 Use of SI Prefixes WIth Units Outside the SI—Some SI prefixes are used with some of the units given in Tables C6, C7, and C8. For example, prefixes for both positive and negative powers of ten are used with the liter, the electronvolt, the unified atomic mass unit, the bar, and the barn. Prefixes for positive powers of ten are used with the metric ton, and prefixes for negative powers of ten are used with the neper and the bel, although the bel is most commonly used in the form of the decibel:

1dB = 0.1 B.

C.1.17 Rules and Style Conventions—A number of rules and style conventions have been adopted internationally for the use of the SI to ensure that scientific and technical communication is not hindered by ambiguity. The most important of these are as follows:

1. Unit symbols are printed in roman (upright) type regardless of the type used in the surrounding text.

2. Unit symbols are printed in lowercase letters except that:

   a. the symbol or the first letter of the symbol is an uppercase letter when the name of the unit is derived from the name of a person; and
   b. the preferred symbol for the liter in the United States is L.

3. When the name of a unit is spelled out, it is always written with a lowercase initial letter unless it begins a sentence.

4. Unit symbols are unaltered in the plural.

5. Unit symbols are not followed by a period unless at the end of a sentence.

6. Symbols for units formed from other units by multiplication are indicated by means of a half-high (that is, centered) dot or space.

   EXAMPLE—N·m or N m

7. Symbols for units formed from other units by division are indicated by means of solidus (oblique stroke,/), a horizontal line, or negative exponents.

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

   However, to avoid ambiguity, the solidus must not be repeated on the same line unless parentheses are used.

   EXAMPLES—

   $\mathrm{m/s^2}$ or $\mathrm{m{\cdot}s^{-2}}$ *but not*: m/s/s
   $\mathrm{m{\cdot}kg/(s^3{\cdot}A)}$ or $\mathrm{m{\cdot}kg{\cdot}s^{-3}{\cdot}A^{-1}}$ *but not*: $\mathrm{m{\cdot}kg/s^3/A}$

   Negative exponents should be used in complicated cases.

8. Prefix symbols are printed in roman (upright) type regardless of the type used in the surrounding text, and are attached to unit symbols without a space between the prefix symbol and the unit symbol. This last rule also applies to prefix names attached to unit names.

   EXAMPLES—

   1 mL (one milliliter)
   1 pm (one picometer)
   1 GΩ (one gigaohm)
   1 THz (one terahertz)

9. The grouping formed by a prefix symbol attached to a unit symbol constitutes a new inseparable symbol (forming a multiple or submultiple of the unit concerned) which can be raised to a positive or negative power and which can be combined with other unit symbols to form compound unit symbols.

   EXAMPLES—

   $2.3\ \mathrm{cm}^3 = 2.3\ (\mathrm{cm})^3 = 2.3\ (10^{-2}\ \mathrm{m})^3 = 2.3 \times 10^{-6}\ \mathrm{m}^3$
   $1\ \mathrm{cm}^{-1} = 1\ (\mathrm{cm})^{-1} = 1\ (10^{-2}\ \mathrm{m})^{-1} = 10^2\ \mathrm{m}^{-1}$
   $5000\ \mu\mathrm{s}^{-1} = 5000\ (\mu\mathrm{s})^{-1}$
   $= 5000\ (10^{-6}\ \mathrm{s})^{-1}$
   $= 5000 \times 10^6\ \mathrm{s}^{-1} = 5 \times 10^9\ \mathrm{s}^{-1}$

   Prefix names are also inseparable from the unit names to which they are attached. Thus, for example, millimeter, micropascal, and meganewton are single words.

10. Compound prefix symbols, that is, prefix symbols formed by the juxtaposition of two or more prefix symbols, are not permitted. This rule also applies to compound prefix names.

EXAMPLE—1 nm (one nanometer) *but not*: 1 mμm (one millimicrometer)

11. An SI prefix symbol (and name) cannot stand alone, but must always be attached to a unit symbol (or name).

EXAMPLE—$5 \times 10^6/\mathrm{m}^3$ *but not*: $5\ \mathrm{M/m}^3$

12. In the expression for the value of a quantity, the unit symbol is placed after the numerical value and a space is left between the numerical value and the unit symbol. The only exceptions to this rule are for the unit symbols for degree, minute, and second for plane angle: °, ′, ″, respectively (see Table C6), in which case no space is left between the numerical value and the unit symbol.

    EXAMPLE—α = 30°22′8″

    This rule means that:

    a. The symbol °C for the degree Celsius is preceded by a space when one expresses the values of Celsius temperatures.
       EXAMPLE—*t* = 30.2 °C *but not*: *t* = 30.2°C or *t* = 30.2° C

    b. Even when the value of a quantity is used in an adjectival sense, a space is left between the numerical value and the unit symbol. (This rule recognizes that unit symbols are not like ordinary words or abbreviations but are mathematical entities, and that the value of a quantity should be expressed in a way that is as independent of language as possible.)

       EXAMPLES—

       a 1 m end gauge *but not*: a 1-m end gage a 10 kΩ resistance *but not*: a 10-kΩ resistance

However, if there is any ambiguity, the words should be rearranged accordingly. For example, the statement "the samples were placed in 22 mL vials" should be replaced with the statement "the samples were placed in vials of volume 22 mL," or "the samples were placed in 22 vials of volume 1 mL," whichever was meant.

NOTE—When unit names are spelled out as is often the case in nontechnical writing, the normal rules of English apply. Thus, for example, "a roll of 35-millimeter film" is acceptable.

C.1.18 Obsolete Units—As stated in the 1990 **Federal Register** notice, metric units, symbols, and terms that are not in accordance with the foregoing interpretation are not accepted for continued use in the United States with the International System of Units. Accordingly, the following units and terms listed in the table of metric units in section 2 of the Act of July 28, 1866 (15 U.S.C. 205) that legalized the metric system of weights and measures in the United States are not accepted for use in the United States.

myriameter
stere
millier or tonneau
quintal
myriagram
kilo (for kilogram).

C.1.19 Additional Information on the SI—Additional information on the SI may be found in NIST Special Publication (SP) 811, *Guide for the Use of the International System of Units (SI)*, by Barry N. Taylor. This publication is for sale by the Superintendent of Documents, but is also available online (as will be this notice) at URL http://physics.nist.gov/cuu. (Although the 1995 edition of SP 811 is the edition currently available in print and online, a new edition that fully reflects the contents of this notice is under preparation and will replace the 1995 edition.)

Although there is no formal comment period, public comments are welcome on a continuing basis. Comments should be submitted to Dr. Barry N. Taylor at the above address.

Dated: June 19, 1998.

Robert E. Hebner,

Acting Deputy Director.

[FR Doc. 98-16965 Filed 7-27-98; 8;45 am]

Billing Code 3510-13-M

Rationale

NOTE—The last two pages of this document (rationale) are not numbered because this portion of the document is also sold separately.

This Report contains information on:

a. SAE-oriented material, such as SAE Metric Policy and reference to the SAE Strategic Plan.
b. Guidance for correct, uniform application of SI (Metric) units within the technical and scientific disciplines and areas served by SAE and its members.
c. Linkage to the primary American National Standard for use of the International System of Units (SI).

This Report does not contain the entire body of authoritative information on SI. Full coverage on the content of SI and related information is set forth in the IEEE/ASTM SI 10-1997, American National Standard; as well as in Appendix C and various documents cited in Section 2 of this Report.

The principal differences between this Report and the previous (June, 1992) version of TSB 003 are:

a. SAE-specific information retained and updated.
b. SI application guidance material retained and updated.
c. SI "core" material deleted, in lieu of reliance on Appendix C and the primary referenced American National Standard for SI.

Relationship of SAE Standard to ISO Standard—This Report (TSB 003) is compatible with the relevant ISO document: ISO 1000, "SI Units and Recommendations for the Use of Their Multiples and Certain Other Units."

Application—This SAE Standard provides selected basic information on the International System of Units (abbreviated SI in all languages) and its application in engineering practice and related areas. The purpose is to provide information on SI and guidance on SI's correct, uniform usage in land, sea, air, and aerospace design, engineering, and manufacturing practices.

This document establishes the rules for the use of SI units in SAE technical reports, including Standards, Recommended Practices, Information Reports; as well as in technical papers, publications, etc. TSB 003 is applicable for governance of SI metric practice throughout SAE operations, internal and external communications, products, and services.

Reference Section

In the SAE Strategic Plan, January 1, 1997, under the Technical Standards Board's implementation of the Vision "To provide world-class standards-related products and services to the global mobility industry," the SAE Vision/Ends Strategies include "H. Encourage and promote the use of metric weights and measures by adopting the system of SI Metrics."

SAE Paper No. 850218—SI Metric for the Practicing Mechanical Engineer, S. R. Jakuba

SAE Book—Metric (SI) in Everyday Science and Engineering, Stan Jakuba, 1993

SAE & ANMC Book—Metrication for the Manager, John T. Benedict, 1992

SAE J390—Dual Dimensioning—1982

The SAE Metric Advisory Committee adopted (Feb. 1997) the ANSI (American National Standards Institute) American National Standard; IEEE/ASTM SI 10-1997 "Standard for Use of the International System of Units (SI): The Modern Metric System"—as the SAE's primary reference for SI. The SI 10 document is the formally designated primary American National Standard for use of the International System of Units.

ISO 1000—SI Units and Recommendations for the use of their multiples and of certain other units, 1992

NIST Special Publication 330—The International System of Units (SI)—1991

U.S. Federal Register Notice, Metric System of Measurement; Interpretation of the International System of Units for the United States, July 28, 1998 (see Appendix C)

NIST Special Publication 304—SI Chart, The Modernized Metric System, 1998

NIST Special Publication SP330—The International System of Units (SI), 1991

NIST Special Publication 811—Guide for the Use of the International System of Units, (SI), 1995

NIST Special Publication 814—Interpretation of the SI for the United States and Metric Conversion Policy for Federal Agencies, 1991

GSA (General Services Administration)—Federal Standard 376B—Preferred Metric Units for General Use by the Federal Government, 1993

U.S. Government Printing Office—Style Manual—1984

U.S. Dept. of Defense Production & Logistics Office—SD-10 Guide for Identification and Development of Metric Standards, 1990

Developed by the SAE Metric Advisory Committee