



Standard Practice for Use of SI (Metric) Units in Maritime Applications (Committee F25 Supplement to IEEE/ASTM SI 10)¹

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This standard has been approved for use by agencies of the Department of Defense.

INTRODUCTION

The International System of Units (SI) was developed by the General Conference on Weights and Measures (CGPM), which is an international treaty organization. The abbreviation *SI*, derived from the French “Le Système International d’Unités,” is used in all languages.

On Dec. 23, 1975, Public Law 94-168, “The Metric Conversion Act of 1975,” was signed by President Ford, committing the United States to a coordinated voluntary conversion to the metric system of measurement. The Act specifically defines the “metric system of measurement” as “the International System of Units as established by the General Conference on Weights and Measures in 1960, and as interpreted or modified for the United States by the Secretary of Commerce.”

On Aug. 23, 1988, President Reagan signed into law P.L. 100-576, the Omnibus Trade and Competitiveness Act of 1988. The Act specifies that “metric” means the modernized metric system (SI). The Act then amended the Metric Conversion Act of 1975 to designate the metric system of measurement as the preferred system of weights and measures for United States trade and commerce.

This practice will help obtain uniform SI practice in the marine industry by providing a technical reference for the International System of Units (SI). The practice is not intended to cover all aspects of SI usage, but to serve as a ready reference especially tailored to the operating needs of the industry. For further information on SI usage and conversion factors for units not found herein, refer to **IEEE/ASTM SI-10**, upon which this practice is based. In the event of a conflict, **IEEE/ASTM SI-10** shall take precedence. (See also NIST Special Publication 811.) Hardware and other standards in SI are currently being developed. [ASTM F1332-99\(2011\)](https://standards.iteh.ai/catalog/standards/sist/210d257b-0233-45bf-9fc7-80547794e7ca/astm-f1332-992011)

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1. Scope

1.1 This practice covers the use of SI, which is comprised of base and derived SI units. Also discussed are non-SI units that have been accepted and recognized by the CGPM as appropriate for limited use or time. Basic rules for style and usage of SI are set forth, as well as methods for conversion from non-SI units to SI units. Tables of quantities used by the marine industry are included, with present units and conversion factors given.

¹ This practice is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.

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2. Referenced Documents

2.1 ASTM Standards:²

IEEE/ASTM SI-10 Standard for Use of the International System of Units (SI): The Modernized Metric System

2.2 NIST Publications:

NIST Special Publication 811 Guide for the Use of the International System of Units (SI)³

NIST Special Publication 330 The International System of Units (SI)³

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

³ Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, <http://www.nist.gov>.

3. Terminology

3.1 Definitions:

3.1.1 *quantity, n*—measurable attribute of a physical phenomenon.

3.1.2 *SI, n*—The universally accepted abbreviation for the International System of Units as defined in the document *Le Système International d’Unités*, 6th Edition, published by the International Bureau of Weights and Measures (BIPM), Sevres, France, 1991, and as interpreted and modified for the United States by the U.S. Department of Commerce. The U.S. version of the defining document is published by the National Institute of Standards and Technology as NIST Special Publication 330.⁴

3.1.3 *unit, n*—reference value of a given quantity as defined by CGPM Resolution or ISO standards. There is only one unit for each quantity in SI.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *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.

4. The Concept of SI

4.1 The International System of Units (SI) was developed to provide a universal, coherent, and preferred system of units for world-wide use and appropriate to the needs of modern science, technology, and international commerce.

4.2 The principal features of SI are:

4.2.1 There is one and only one unit for each quantity.

4.2.2 The system is fully coherent.

4.2.3 Designated prefixes can be attached to units to form multiples and submultiples of ten raised to a power. Use of the prefixes provides for convenient numerical values when the magnitude of a quantity is stated, and avoids the need for many insignificant zeroes. The system is decimal, the same as the commonly used numerical system.

4.2.4 Units and prefixes are represented by standardized and internationally recognized symbols.

4.3 A few specifically accepted non-SI units are permitted in conjunction with SI.

4.4 SI units, acceptable non-SI units, and prefixes are discussed in Sections 5 and 6.

5. SI Units

5.1 SI includes two classes of units:

5.1.1 Base units and

5.1.2 Derived units.

5.2 *Base Units*—The International System of Units is based on seven base units, listed in Table 1, which by convention are regarded as dimensionally independent.

5.3 *Derived Units*—Derived units are formed by the algebraic combination of base units and derived units. Derived units with special names are listed in Table 2.

5.4 *Temperature*—The SI unit of thermodynamic temperature is the kelvin, and this unit is properly used for expressing thermodynamic temperature and temperature intervals. The degree Celsius is equivalent to kelvin with a different zero point on the scale. Celsius temperature t equals kelvin temperature minus 273.15 ($t = T - T_o$, where $T =$ Kelvin and $T_o = 273.15$).

5.5 *SI Prefixes*—The prefixes and symbols shown in Table 3 are used to form decimal multiples and submultiples of SI units.

5.6 Selection of Prefixes:

5.6.1 A prefix should be selected so that the numerical value of the unit expressed will fall between 0.1 and 1000. An exception to this rule arises in the preparation of tables of values of the same quantity and in discussion of such values within a given context, when it is better to use the same unit multiple. Also, for certain applications, one particular multiple will customarily be used; for example, use of the millimetre for linear dimensions in engineering drawings.

5.6.2 Compound prefixes should not be used; for example, use GJ, not kMJ.

5.6.3 Prefixes should preferably not be used in the denominator of compound units. Example, use V/m not mV/mm. The exception is the kilogram as it is the base unit: J/kg, not kJ/g.

5.6.4 Errors in calculation may be avoided by using powers of ten with the units rather than prefixes.

6. Non-SI Units in Use with SI

6.1 *Units in Use with SI*—Certain units that are not SI have been accepted for use with SI units. Some of these units, currently recognized as acceptable for use with SI, are listed in Table 4 and Table 5.

6.2 *Time*—The SI unit of time is the second. This unit is preferred and should be used when practical, particularly in technical calculations.

6.3 *Plane Angle*—The SI unit of plane angle is the radian. When the radian is not a convenient unit, the degree should be used with decimal submultiples. Minutes and seconds should be used only when required (as in navigation).

⁴ The U.S. edition of the English translation of the BIPM SI publication differs from the translation in the BIPM SI publication only in the following usage: (1) The dot is used as the decimal marker and (2) the spelling of English-language words, for example, “meter,” “liter,” and “deka” are used instead of “metre,” “litre,” and “deca” in accordance with the *U.S. Government Printing Office Style Manual*, which follows *Webster’s Third New International Dictionary* rather than the *Oxford Dictionary* used in many English-speaking countries.

The spelling of “meter” and “liter” in preference to “metre” and “litre” is recommended by the U.S. Department of Commerce as preferred for U.S. use and is mandated by the Department of Commerce for use by all agencies of the Federal government.

TABLE 1 SI Base Units

Quantity	Base SI Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd



TABLE 2 SI Derived Units with Special Names

Quantity	Name of Derived SI unit	Symbol	Expressed in Terms of Base and Derived SI Units
Angle, plane	radian	rad	mm = 1
Angle, solid	steradian	Sr	m ² /m ² = 1
Frequency	hertz	Hz	s ⁻¹
Force	newton	N	kg·m/s ²
Pressure, stress	pascal	Pa	N/m ²
Energy, work, quantity of heat	joule	J	N·m
Power, radiant flux	watt	W	J/s
Electric charge, quantity of electricity	coulomb	C	A·s
Electric potential, potential difference, electromotive force	volt	V	W/A
Electric capacitance	farad	F	C/V
Electric resistance	ohm	Ω	V/A
Electric conductance	siemens	s	A/V
Magnetic flux	weber	Wb	V·s
Magnetic flux density	tesla	T	Wb/m ²
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	cd·sr
Illuminance	lux	lx	lm/m ²
Celsius temperature ^A	degree Celsius	°C	K
Activity (of a radionuclide)	becquerel	Bq	s ⁻¹
Absorbed dose	gray	Gy	J/kg
Dose equivalent	sievert	Sv	J/kg

^A See 5.4.

6.4 *Area*—The SI unit of area is the square metre. The hectare (ha) is a special name for square hectometre (hm²). Large land or water areas are generally expressed in hectares or in square kilometres.

6.5 *Volume*—The SI unit of volume is the cubic metre. The cubic metre, or one of its multiples or submultiples, is preferred for all applications. The special name litre has been approved by the CGPM for the cubic decimetre.

6.6 *Mass*—The SI unit of mass is the kilogram. The kilogram, or one of the multiples or submultiples formed by attaching an SI prefix to gram, is preferred for all applications. For large masses (such as have been expressed in tons), the megagram is the appropriate unit. The term metric ton should be restricted to commercial and maritime usage, and no prefixes should be used with it. To avoid confusion, use of the term “tonne” to indicate metric ton is discouraged.

7. Mass, Force, and Weight

7.1 SI, being coherent, is different from the older metric systems in the use of distinctly separate units for mass and force. In SI, the unit of force, the newton (N), is derived as the laws of physics dictate, instead of being related to gravity, and is defined as being equal to the force that imparts an acceleration of unit (1 m/s²) to a unit mass, the kilogram (kg).

7.1.1 *Mass*—The mass of a body is a measure of its inertia, that is, its resistance to a change in its motion. In practical terms, mass represents the quantity of matter in a body (not to be confused with amount of substance expressed in moles). The SI unit of mass is the kilogram (kg).

7.1.2 *Force*—Force is the mechanical action on a body resulting from physical contact with another body or the action resulting from gravitational or electromagnetic fields. The SI unit of force is the newton (N).

7.1.3 *Weight*—The weight W of a body is the effective gravity force acting on it and equals the product of its mass m and the local acceleration of free fall, g , so that $W = mg$. In SI, weight is measured in newtons (N). Because the acceleration of gravity (the acceleration of free fall) varies slightly over the surface of the earth, the weight of a body varies accordingly, whereas its mass is a constant.

7.1.4 *Discussion*—The existence of clearly separate units for mass and force in SI contrasts with the widespread use of the units lb and kg for both mass and force. Whereas the word “weight” has been commonly used when mass is intended or implied, especially in commerce and everyday life, this use should in time disappear with growing acceptance and use of SI units, and the word *mass* (rather than *weight*) will be used when mass is meant. The use of weight for mass should be avoided altogether in scientific and technical communication.

8. Rules for Style and Usage of SI

8.1 Rules for Writing Unit Symbols:

8.1.1 Particular care must be taken to use the correct symbols for units and prefixes (for example, K for kelvin, k for kilo, M for mega, m for milli). When using systems with limited character sets, as in Telex transmission or computer printout, the standard symbols cannot be used. For these purposes, refer to ISO 2955 or ANSI X3.50.

8.1.2 Unit symbols are symbols and do not vary from singular to plural.

8.1.3 Unit symbols should be printed in roman (upright) type, regardless of the type style used in the surrounding text.

8.1.4 Unit symbols are not followed by a period except when used at the end of a sentence.

8.1.5 The numerical value associated with a symbol should be separated from that symbol by a space. For example, 25.4 mm, not 25.4mm. The only exception to this rule is that no space is left between the numerical value and the symbols of degree, minute, and second of plane angle and degree Celsius.

8.1.6 Unit symbols should be used in preference to the unit names except when a number written out in words precedes the unit; for example “seven metres” not “seven m.”

8.2 Rules for Writing Unit Names:

8.2.1 The first letter of a unit name is not capitalized except at the beginning of a sentence or in capitalized material such as a title.

8.2.2 Plurals of unit names are formed in the ordinary manner, except for lux, hertz, and siemens, which remain the same.

8.2.3 No space or hyphen is used between a prefix and the unit name; for example, kilonewton.

8.3 Product, Quotient, and Powers:

8.3.1 To indicate the product of units when using their names, a space is left between the names (for example, newton metre). When using symbols, a centered dot should be placed between the symbols (for example, N·m).

8.3.2 To indicate the quotient of units when using their names use the word “per” (for example, metres per second). When using unit symbols, a solidus (/) or negative exponent should be used (for example, m/s or m·s⁻¹). Do not use more

TABLE 3 SI Prefixes

exa	E	10 ¹⁸	1	000	000	000	000	000	000	000									
peta	P	10 ¹⁵		1	000	000	000	000	000	000									
tera	T	10 ¹²			1	000	000	000	000	000									
giga	G	10 ⁹				1	000	000	000	000									
mega	M	10 ⁶					1	000	000	000									
kilo	k	10 ³						1	000	000									
hecto ^A	h	10 ²							100	000									
deka ^A	da	10 ¹							10	000									
deci ^A	d	10 ⁻¹							0.1	000									
centi ^B	c	10 ⁻²							0.01	000									
milli	m	10 ⁻³							0.001	000									
micro	μ	10 ⁻⁶							0.000	001									
nano	n	10 ⁻⁹							0.000	000	001								
pico	p	10 ⁻¹²							0.000	000	000	001							
femto	f	10 ⁻¹⁵							0.000	000	000	000	001						
atto	a	10 ⁻¹⁸							0.000	000	000	000	000	001					

^A To be avoided where practical.

^B Usually avoided, but used in some disciplines.

TABLE 4 Non-SI Units in Use with SI

Quantity	Unit	Symbol	Definition
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3600 s
	day	d	1 d = 24 h = 86 400 s
plane angle	degree	°	1° = (π/180) rad
	minute	'	1' = (1/60)° (π/10 800) rad
	second	"	1" = (1/60)' = (π/648 000) rad
volume	litre	L	1 L = 1 dm ³ = 10 ⁻³ m ³
mass	metric ton	t	1 t = 10 ³ kg

TABLE 5 Units in Use Temporarily with SI^A

Name	Value in SI Unit (exact)
nautical mile (nmi)	1852 m
knot (kn)	nmi/h = (1852/3600) m/s
Hectare (ha)	10 ⁴ m ²
bar ^B	100 kPa
curie (Ci)	3.7 × 10 ¹⁰ Bq
roentgen (R)	2.58 × 10 ⁻⁴ C/kg
rad (rad) ^C	1 × 10 ⁻² Gy
rem (rem)	1 × 10 ⁻² Sv

^A Because their usage is already well established, these units may be used subject to further review.

^B Usage is restricted to meteorology.

^C If there is risk of confusion with the symbol for radian, rd may be used as the symbol for rad.

than one solidus in the same expression. Use parentheses to avoid any ambiguity (consider m/s·A can mean m/(s·A) or (m/s)·A).

8.3.3 To indicate powers when using unit names, the words “square,” “cubic,” “squared,” “cubed,” and so forth should be used (for example, square metre, second squared). When using unit symbols, powers are indicated by the use of an exponent (for example, m³).

8.4 Numbers:

8.4.1 At present, the period will be used for the decimal marker. For numbers of less than one, a zero should precede the decimal; for example, 0.964.

8.4.2 Recommended international practice calls for the use of a half space to separate large numbers into groups of three. Do not use a comma. The digits should be separated into groups of three counting from the decimal point toward the left and the right, and using a small space to separate the groups. In numbers of four digits, the space is usually not necessary except to provide uniformity in tables, columns, and so forth. For example, 16 390, 1.828 8 or 1.8288, 4 536 or 4536.

9. Conversion and Rounding Methods

9.1 *Soft Conversion*—Soft conversion is the process of changing the non-SI measurement language to equivalent SI units within acceptable measurement tolerances without changing the physical configuration. In other words, the item described is the same item both before and after conversion.

9.2 *Hard Conversion*—Hard conversion is the change of design and use of measures to SI as if non-SI units did not exist, namely the use of integers and round numbers, in SI, as the basis of design. Although the term is in general use, it is technically incorrect when applied to specific items because no “conversion” takes place; rather, a new item, designed in SI units (requiring a new identification), is created to replace the old item.

9.3 *Conversion Factors*—Table 6 contains conversion factors for units commonly used in the marine field.

9.4 *Precision*—When converting, care must be given to the precision desired. The number of significant digits retained in the answer should be such that accuracy is neither sacrificed nor exaggerated. Specified quantities should first be multiplied by the exact conversion factor and then rounded to the appropriate number of significant digits. Do not round either the conversion factor or the quantity before performing the multiplication, as accuracy would be reduced. Use appropriate prefixes to eliminate insignificant, leading, or trailing zeroes.

9.5 *Rounding*—The rounding required by conversion and computation in SI units should be done using the following rules for the three general cases:

9.5.1 Where the digit immediately following the last digit to be retained is less than 5, the last digit retained should not be changed.

TABLE 6 *Continued*

ISO No. ^A	Quantity/Areas of Use	Present Units	Preferred SI Units	Units Permitted for Use with SI ^B	Conversion Factors
1	2	3	4	5	6
	Capacity of air compressors, fans, large pumps	foot ³ per minute	cubic metre per second (m ³ /s)		1 ft ³ /min = 4.719 474 E – 04 m ³ /s
				cubic metre per hour (m ³ /h)	1 ft ³ /min = 1.699 011 E + 00 m ³ /h
	Capacity of most pumps	gallon per minute	cubic metre per second (m ³ /s)		1 gal/min = 6.309 020 E – 05 m ³ /s
				litre per second (L/s)	1 gal/min = 6.309 020 E – 02 L/s
	Barrel per day	barrel per day	cubic metre per second (m ³ /s)		1 bbl/d = 1.840 131 E – 06 m ³ /s
				cubic metre per day (m ³ /d)	1 bbl/d = 1.589 873 E – 01 m ³ /d
	Barrel per nautical mile	barrel per nmi	cubic metre per metre (m ³ /m)		1 bbl/nmi = 8.584 627 E – 05 m ³ /m
				cubic metre per nmi (m ³ /nmi)	1 bbl/nmi = 1.589 873 E – 01 m ³ /nmi
1-6.1	<i>Time:</i> As at present	day (d) hour (h) minute (min) second (s)	second (s)	day (d) hour (h) minute (min)	1.0 ^C 1.0 ^C 1.0 ^C 1.0 ^C
1-7.1	<i>Angular velocity:</i> Machine design	radian per second	radian per second (rad/s)		1.0 ^C
1-7.1a	<i>Angular acceleration:</i> Machine design	radian per second ²	radian per second squared (rad/s ²)		1.0 ^C
1-9.1	<i>Velocity:</i> Ship speed	knot ^E	metre per second (m/s)	knot	1 knot = 5.144 444 E – 01 m/s 1.0 ^C
	Fluid velocity, linear velocity of machinery parts, speed of cables, ropes, wires	foot per second	metre per second (m/s)		1 ft/s = 3.048 000 E – 01 m/s ^C
1-10.1	<i>Acceleration:</i> Machine design Vibration	foot per second ²	metre per second squared (m/s ²)		1 ft/s ² = 3.048 000 E – 01 m/s ^{2C}
2-3.1	<i>Frequency:</i> Electrical and Electronics	cycle per second	hertz (Hz)		1.0 ^C
2-3.2	<i>Rotational speed:</i> Rotational speed of machinery	revolutions per minute (r/min)	radian per second (rad/s)	r/min	1 rpm = 1.047 198 E – 01 rad/s 1.0 ^C
3-1.1	<i>Mass:</i> Deadweight, displacement lightweight ballast, fresh water and fuel oil capacity	ton (long) ^H	megagram (Mg)		1 ton = 1.016 047 E + 00 Mg
				metric ton (t)	1 ton = 1.016 047 E + 00 t
	Lifting capacity, test load and SWL (safe working load, rated) of cranes, booms, and winches	ton pound	kilogram (kg)	metric ton (t)	1 ton = 1.016 047 E + 00 t 1 lb = 4.535 924 E – 01 kg
	General stores, pieces of equipment	pound (lb) hundred weight (cwt)	kilogram (kg) kilogram (kg)		1 lb = 4.535 924 E – 01 kg 1 cwt = 5.080 235 E + 01 kg
3-1.1a	<i>Moment of mass:</i> Engineering calculations	slug pound foot ton foot	kilogram (kg) kilogram metre (kg·m) megagram metre (Mg·m)		1.459 390 E + 1 kg 1 lb-ft = 1.382 549 E – 01 kg·m 1 ton foot = 3.096 911 E – 01 Mg·m
	Trimming moments	ton foot	megagram metre (Mg·m)	metric ton metre (t·m)	1 ton-ft = 3.096 911 E – 01 t·m 1 ton foot = 3.096 911 E – 01 Mg·m
				metric ton metre (t·m)	1 ton-ft = 3.096 911 E – 01 t·m
3-1.1b	<i>Mass flow:</i> Liquid flow rates	ton per hour	kilogram per second (kg/s)		1 ton/h = 2.822 352 E – 01 kg/s
				metric ton per hour (t/h)	1 ton/h = 1.016 047 E + 00 t/h
	Gas and steam flow rates	pound per hour	kilogram per second (kg/s)		1 lb/h = 1.259 979 E – 04 kg/s
				kilogram per hour (kg/h)	1 lb/h = 4.535 924 E – 01 kg/h
3-1.1c	<i>Unit displacement:</i> Displacement per unit of immersion	ton per inch	kilogram per metre (kg/m)		1 ton/in. = 4.000 185 E + 04 kg/m
				metric ton per centimetre (t/cm)	1 ton/in. = 4.000 185 E – 01 t/cm