Guidelines for the Use of SI Units in Technical Writing and Presentations

Donald W. Hillger[1] and Louis F. Sokol[2]

Abstract

Beginning in 1975, the American Meteorological Society (AMS) adopted a strong International System of Units (SI) policy for its publications. AMS policy on SI units is explained in the *Authors' Guide,* published in 1983. This article serves as a review and update on the use of SI units in technical writing. Authors should use SI-unit guidelines both in submission of journal articles as well as in "camera-ready" publications for the AMS.

These guidelines, based on agreements among many international and national standards organizations, will help avoid confusion in the use of SI units and terminology. Footnotes are used to reflect current AMS editorial policy.

1. Introduction

The AMS adopted a policy of making the use of the International System of Units (SI or metric system) standard in all American Meteorological Society (AMS) publications beginning in 1975 (AMS, 1974). This policy was made wisely, based on the near worldwide acceptance of SI as a recognized international standard. SI units are well defined and documented and form a coherent set of units for all physical quantities.

The AMS has done a fine job of implementing this new policy in its publications. AMS policy on the SI was updated recently (AMS, 1983).[3] The correct usage of SI is the combined responsibility of the authors of an article, as well as the reviewers, and the acceptance editor. The authors are required to use SI, and the reviewers are encouraged to note irregularities. Finally, editing assures that SI symbols and terminology are correct. This process of "checks and balances" produces a technically superior end result. Few cases of incorrect or improper SI usage can be found in AMS publications that are a result of the above three-part process. However, when this process is not followed the results can be far from perfect. Most notable are the conference volumes (preprints and reprints) that the AMS prints every year. For these volumes the AMS requires camera-ready copy directly from the authors, so there is a greater possibility of nonstandard or improper use of SI symbols and terminology. One only has to look through a conference volume or witness a conference presentation to see examples of incorrect usage.

TABLE 1. International System of Units (SI).

Quantity	Name	Symbol
	SI Base Units	
length	meter (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
	SI Supplementary Units	
plane angle	radian	rad
solid angle	steradian	sr

* Both spellings are acceptable. (The AMS prefers meter.)
** See Appendix C.

This article provides a set of guidelines for the use of SI units, to help authors prepare their manuscripts according to accepted standards. These guidelines are not arbitrary, but are based on agreements among various international and national standards organizations (including the General Conference of Weights and Measures [GCPM] and the International Organization for Standardization [ISO], as well as the National Bureau of Standards [NBS] and the American Society for Testing and Materials [ASTM] in the United States). Appendix A lists relevant publications by several standards organizations. Much can be said for standards and their aid to international communication.

The following sections do not express any real change in SI units, symbols, or terminology (AMS, 1983). However, since some of these units are not in everyday use in the United States it is not always clear to authors what is correct. It is unfortunate that the United States has not adopted a stronger metric policy (See appendix B). Scientists are leaders in the use of SI, and should set correct examples for others to follow.

2. Brief review of the SI units and symbols

SI units are divided into three classes: 1) base units, 2) supplementary units, and 3) derived units. There are only seven base units and two supplementary units, as given in Table 1. The base units represent independent quantities. Units for all other quantities are derived from base and supplementary units in a coherent manner. Examples of derived units with special names are given in Table 2. Many other derived units,

[1] Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO 80523

[2] United States Metric Association (USMA), 255 Mountain Meadows Road, Boulder, CO 80302.

[3] The *Authors' Guide* is available from AMS for $5 plus $2 postage and handling.

such as for area, volume, speed, etc. are also combinations of the base units, but they lack special names. There are also two sets of units, not part of SI, one of which consists of units that can be used indefinitely, and the other consists of units that can be used "temporarily". Included in the former are units for time and plane angle, as well as the liter and metric ton as shown in Table 3. Two of the temporary units will be discussed in Section 4. Finally, Table 4 gives the prefixes for decimal multiples and submultiples of SI units.

3. Rules for SI names

Specific rules exist for use of *names* of both SI base and derived units. Separate rules for SI symbols appear in the next section.

1) Capitalization: All base or derived units and prefixes begin with a lower case letter, except for Celsius in degree Celsius. (Note that degree is lower case, but Celsius is capitalized.) All other units, even if named after a person, are not capitalized when spelled out, as in pascal and kelvin.
2) Multiple Units: Multiple and submultiple units are spelled as one word, as in kilopascal and millimeter.
3) Compound Units: Names for compound units that are products can be separated by a space or a hyphen, as in newton meter or newton-meter. Quotients use the word "per" as in meter per second.
4) Plurals: Unit names are followed by a plural "s" except when unity or less than unity values are expressed. Examples are 22 micrometers and 0.46 micrometer. The units hertz, lux, and siemens are excepted.
5) Pronunciation: All prefixes are accented on the first syllable. The worst offense is the mispronunciation of KIL-o-meter as ki-LOM-eter. The latter is a widely used pronunciation in the United States. But like the word "ain't", common usage does not make it correct.

   A related misuse is the word micron, which actually is micrometer. This "old metric" term is no longer acceptable. All length measurements in SI have the meter as their root word. Likewise the angstrom should be avoided and nanometer should be used. (1 nm = 10 Å.)

TABLE 2. SI derived units with special names.

	SI Unit		
Quantity	Name	Symbol	Expression in terms of other units
frequency	hertz	Hz	s^{-1}
force	newton	N	$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	$N \cdot m^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$
power, radiant flux	watt	W	$J \cdot s^{-1}$
quantity of electricity, electric charge	coulomb	C	$A \cdot s$
electric potential, potential difference, electromotive force	volt	V	$W \cdot A^{-1}$
capacitance	farad	F	$C \cdot V^{-1}$
electric resistance	ohm	Ω	$V \cdot A^{-1}$
electric conductance	siemens	S	$A \cdot V^{-1}$
magnetic flux	weber	Wb	$V \cdot s$
magnetic flux density	tesla	T	$Wb \cdot m^{-2}$
inductance	henry	H	$Wb \cdot A^{-1}$
temperature	degree Celsius	°C	K
luminous flux	lumen	lm	$cd \cdot sr$
illuminance	lux	lx	$lm \cdot m^{-2}$
activity (radioactive)	becquerel	Bq	s^{-1}
absorbed dose	gray	Gy	$J \cdot kg^{-1}$
dose equivalent	sievert	Sv	$J \cdot kg^{-1}$

TABLE 3. Units in use with SI indefinitely.

Name	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3 600 s
day	d	1 d = 24 h = 86 400 s
degree	°	$1° = (\pi/180)$ rad
minute	′	$1' = (1/60)° = (\pi/10\,800)$ rad
second	″	$1'' = (1/60)' = (\pi/648\,000)$ rad
liter (litre)*	L or l**	$1 L = 1 dm^3 = 10^{-3} m^3$
metric ton or tonne	t	$1 t = 1 Mg = 10^3 kg$
hectare	ha	$1 ha = 1 hm^2 = 10^4 m^2$

* Both spellings are acceptable. (The AMS prefers liter.)
** L is preferred in order to avoid confusion with the numeral 1.

a. Rules for SI symbols

Each SI unit has a unique *symbol* (sometimes miscalled an abbreviation) that is the same in every language. By using correct symbols there is no confusion. The rules for symbols are different from those for the unit names given in the last section.

1) Capitalization: Lowercase is used except when the symbol represents a unit named after a person (e.g. N for newton) or is the capital L for liter. (A lowercase l is likewise acceptable for liter.) A symbol consisting of two letters when named after a person is written with the first letter in uppercase (e.g. Pa for pascal). Prefixes are lower-case letters except for those mega and higher in value. (See Table 4.) Examples are km for kilometer, kPa for kilopascal, and MHz for megahertz.
2) Plurals: SI symbols are the same for singular and plural amounts. A plural "s" is never used with SI symbols. For example, 1 km and 14 km use the same symbol.
3) Spacing: A space is used to separate the symbol from the numeric value, except for the degree, minute, and second symbols, which are not separated from the number. Examples are 12 cm and 30°50′22″ latitude. However, temperature can be expressed as either 18 °C or 18°C, with or without the space. (No space is preferred.)
4) Periods: SI symbols are never treated as abbreviations and are therefore never followed by a period unless the symbol is the last item in a sentence.
5) Compound Units: Products of units use the raised dot as a multiplier sign, as in N · m for newton meter. If it is impractical to print the raised dot, a dot on the line is

TABLE 4. SI prefixes.

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto*	h
10^{1}	deka*	da
10^{-1}	deci*	d
10^{-2}	centi*	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

* Use should be avoided when possible except for the nontechnical use of centimeter and in special units for area and volume.

acceptable.[4] Quotients use a slash (or solidus) or more preferably a negative exponent as in m/s or $m \cdot s^{-1}$ for meter per second. The dot between units eliminates the common mistake of ms^{-1} instead of $m \cdot s^{-1}$. To avoid using more than one solidus use parentheses or negative exponents as in J/(kg · K) or $J \cdot kg^{-1} \cdot K^{-1}$.

If certain symbols, such as the Greek μ and Ω, are not available on the typewriter or word processor, an effort should be made to enter these symbols manually. The unavailability of lower case letters on some graphics software is also a problem. Plots may have to be produced with symbols only in uppercase. However, more sophisticated graphics packages now employ both upper- and lower-case letters and other symbols.

b. Rules for numerical values

There are rules for the representation of *numerical values.*

1) Decimal Marker: A period or dot is preferred in the United States as a decimal marker. In Europe the comma is used as a decimal marker.
2) Number Grouping: The above variation in practice precludes the use of the comma as a separator between groups of three numbers in longer numerical values. Groups of three letters should be separated by a space with no punctuation, as in 763 076.21 m or 0.023 45 mV. A group of four digits need not be separated unless in a tabular column with longer numbers. Exponential notation or an appropriate prefix may eliminate the need for this rule.
3) Fractions: Decimal notation is preferred to the use of common fractions, and zero precedes the decimal marker in values less than one, as in 0.25 g.

[4] The AMS uses a space between the elements of compound units in its technical journals.

4. Special considerations for meteorological units

For temperature the SI base unit is the kelvin (K), a unit of thermodynamic temperature. However, the degree Celsius is approved as a derived SI unit. The equation

$$t(^\circ C) = T(K) - 273.15\ K$$

is used to define the relationship between the two temperatures. (A degree Celsius is equal to a kelvin when used as an interval or difference in temperature, but not as an absolute value.) The unit kelvin should not be preceded by the word or symbol for degree when using either the name or symbol for kelvin. However, the degree Celsius requires the word or symbol for degree. Note that the symbol C alone stands for coulomb (electric charge).

For pressure the SI derived unit is the pascal, which is equal to a newton per square meter. However, since the pascal is an extremely small unit, the kilopascal is more appropriate for atmospheric pressures. A value of 100 kPa is equal to 1000 mb. The unit bar and its submultiples (e.g. millibar) are non-SI and are to be avoided. The US government only recently recommended the phasing out of the bar (Federal Register, 1985). The World Meteorological Organization (WMO) uses the hectopascal, which is equal to the millibar; however, the prefix hecto is not a preferred multiplier (See Table 4). Therefore, the use of kilopascal is recommended, and the use of millibar is discouraged.

The nautical mile and the knot (nautical mile per hour) will continue to be used for some time, especially with their wide use in navigation and aviation. Table 5 gives these "temporary" units and their symbols as recognized by the AMS. The recommended symbol for nautical mile is n mi in order to avoid confusion with the symbol nm for nanometer. Obviously the two are widely different, but the use of the symbol m should be avoided for mile and should be used only for meter in order to avoid any confusion between the two units.

The logarithmic decibel (dB) is not an SI unit. It is merely a ratio or difference. However, in keeping with SI rules the dB symbol should not be modified by the attachment of a qualifier such as in dBZ[5]. The same holds true for alternating and direct current voltages, as in V (*ac*) and V (*dc*). A space should be placed between the unit and the qualifier in parentheses.[6]

TABLE 5. Examples* of temporary units to be used with SI.

Name	Symbol	Value in SI Units
nautical mile	n mi**	1 n mi = 1852 m
knot	kt**	1 kt = 1 n mi $\cdot h^{-1}$ = (1852/3600) $m \cdot s^{-1}$

*Other temporary units are given in AMS (1983).
**Symbols recognized by AMS but not by the International Committee for Weights and Measures (CIPM).

[5] The AMS accepts dB*Z* without a space between the unit and the qualifier.
[6] The AMS uses V_{ac} and V_{dc}.

5. Notes on representing dates and times

In the United States the common practice is to write numerical dates in the order month-day-year. In many other parts of the world the day is given before the month as in day-month-year. The latter chronological progression makes more sense than the mixed chronological order used in the United States; therefore, a unique solution is to place the year first, followed by the month and day in descending chronological order as in year-month-day. This practice is used in many computer systems. An example of an all-numeric date report is 1986-02-15.

The AMS recommends dates be written in ascending order (day-month-year) with the month spelled out. However, confusion is possible when all numbers are used; so ISO recommends placing the components of the date in descending chronological order, as in 86-01-09. Then there is no confusion as to whether 01-09-86 means January 9th (in the United States) or September 1st (in Europe).

In expressing times the use of universal time is preferred, except when 24-hour local time makes more sense. The new standard for time is Coordinated Universal Time (UTC) and no longer Greenwich Mean Time (GMT).[7] Coordinated Universal Time is a 13-year-old international standard kept by 150 atomic clocks around the world (Lohr, 1985; *Time,* 1985). The two time standards are equivalent for all practical purposes, but GMT terminology is being phased out. International time-broadcast stations, such as WWV and WWVH in the United States, as well as many shortwave broadcast stations have used UTC for years.

6. Concluding remarks

The International System of Units is a well-defined and coherent system of units with worldwide acceptance. Each SI unit has a unique symbol, with the exception of the liter that can be represented by L or 1. (The uppercase L is preferred, in order to avoid confusion with the numeral 1). The use of correct symbols and terminology is necessary for accurate technical writing and presentation. The AMS has wisely made the use of the SI standard in its publications. However, in conference reports and presentations, which are not technically edited by the AMS, there is a greater chance for improper or incorrect SI usage. These guidelines, as agreed upon by many international and national standards organizations, will help avoid any confusion in SI usage. Authors are urged to adopt their use in all their work and should keep this article for handy reference, along with AMS (1983).

Acknowledgments. The authors wish to thank the many national and international groups responsible for SI standards. The AMS is also congratulated for its decision to use SI units long before many other publications.

Portions of the material for this article were extracted from International Bureau of Weights and Measures (BIPM) and United States Metric Association (USMA) publications. We thank Bobbie Schwinger for typing the manuscript.

[7] Beginning in 1987 the AMS will use UTC.

Appendix A. Bibliography

ANSI/IEEE Standard 268-1982, 1982: American National Standard on Metric Practice. American National Standards Institute, New York, NY, 48 pp.

ASTM Standard for Metric Practice, E380-85, 1985: American Society for Testing and Materials, Philadelphia, 42 pp.

Federal Standard 376A, 1983: Preferred Metric Units for General Use by the Federal Government, General Services Administration. 13 pp.

ISO Standards Handbook No. 2, 1981: Units of Measurement, (Contains ISO31 and ISO1000), International Organization for Standardization (ISO), Geneva, Switzerland, 234 pp.

The International System of Units (SI), 1985: 5th Edition, (French and English), International Bureau of Weights and Measures (BIPM), Sevres, France, 110 pp.

Appendix B. Brief review of metric status in the United States

When the US Congress passed the (voluntary) Metric Conversion Act in 1975 there was an initial urgency to get on with the job. Plans were made to rather quickly adopt metric measurements in certain sectors of our economy, including such high visibility items as metric road signs and metric weather reports. However, due to initial negative public reaction, such plans have been indefinitely postponed. Rather, most *metrication* (metric transition) has not been in high visibility. Our everyday lives show little outward sign of metric.

The United States stands virtually alone in an otherwise metric world. The other English-speaking nations have had much more success in their metrication. Notable examples of near total metric adoption have occurred in Australia, New Zealand, and Canada. Further impetus for metrication will come from the European Economic Community (EC), which has set a 1990 deadline for the use of SI units on all documentation of imported products. People's Republic of China also set a 1990 deadline for metric transition.

Businesses that deal internationally have seen the need to move to metric. Probably most notable is the auto industry. Virtually all new cars use metric components and many are entirely metric. Likewise packaged liquor is sold in metric fills for export reasons, and who hasn't come across the ubiquitous one-, two-, and three-liter soft-drink containers? More and more industries are changing as required, not by law, but by the market place. Metric is not dead in the United States, although outwardly it may appear that way.

Appendix C. On the use of mass and weight terminology

The Third General Conference of Weights and Measures (GCPM) in 1901 declared 1) The kilogram is the unit of *mass* . . . 2) The word *weight* denotes a quantity of the same nature as force; the weight of a body is the product of its mass and the acceleration due to gravity . . . It is recommended that authors *not* use weight in reference to the gram or kilogram.

References

AMS, 1974: SI Units to be Used in AMS Journals, *Bull. Amer. Meteor. Soc.,* **55,** 926–930.

AMS, 1983: American Meteorological Society, *Authors' Guide,* ISBN 0-933876-53-X, 38 pp.

Federal Register, 1985: Federal Agency Actions Involving the Use of the Metric System in Providing Meteorological Services and Supporting Research (Office of Secretary, Department of Commerce). Vol. 50, No. 123, Wednesday, 26 June, Notices, p. 26393.

Lohr, S., 1985: "For Greenwich Clocks, Time is Running Out." *New York Times,* 10 November, Sec. 1, p. 23, col. 1.

"Britain; Time to go off the Clock," *Time,* 25 Nov. 1985, p. 77. ●