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An American National Standard

Metric Practice Guide for the Welding Industry

American Welding Society

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ANSI

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Metric Practice Guide for the Welding Industry

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Prepared by
AWS A1 Committee on Metric Practice

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This metric practice guide is based on the International System of Units (SI) as defined in the *U.S. Federal Register* notice of July 28, 1998, "Metric System of Measurement: Interpretation of the International System of Units for the United States." It includes the base units, derived units, and rules for their use. Also covered are conversion factors and rules for their use in converting inch-pound units to SI units.

Recommendations are presented for style and usage in such areas as prefixes, punctuation, number grouping, etc. There are also suggestions to industry for managing the transition.

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Foreword

(This Foreword is not a part of AWS A1.1:2001, *Metric Practice Guide for the Welding Industry*, but is included for information purposes only.)

The present AWS Policy on Metrication states, in part, that "The AWS supports a timely transition to the use of SI units. The AWS recognizes that the inch-pound system of units will eventually be replaced by the SI units. To delay the transition to SI units and to lengthen unnecessarily the transition period results in greater costs and confusion and increases the loss of compatibility with the international market."

At the present time, the U.S. stands alone as the only industrial country that still predominantly uses the inch-pound units of measurement. Since the signing of the Metric Act of 1975 by President Ford and an initial flurry of transition, the voluntary feature of the Act allowed the impetus to stagnate. We now find ourselves at odds not only with other industrial countries, but also, in many cases, with each other.

Many major companies—including General Motors Corporation, Ford Motor Company, DaimlerChrysler Corporation and an estimated 70% of the Fortune 500—have made the switch in some aspect of their businesses. But smaller firms, typically those with fewer international interactions, have been slower to change.

More recently, the Omnibus Trade and Competitiveness Act, which was signed by President Reagan in August 1988, designated the SI version of the metric system of units as preferred for U.S. trade and commerce. Specifically, this Act requires each Federal Agency to use the metric system in its procurements, grants, and other business-related activities.

A Metric Practice Subcommittee was formed under the AWS Committee on Definitions, Symbols, and Metric Practice in 1973 to provide guidance to the welding industry in the use of and conversion to SI units. The continued interest in metric practice within the AWS resulted in the reorganization of the former Metric Practice Subcommittee into the present AWS A1 Committee on Metric Practice. Because a comprehensive document relating specifically to welding nomenclature was not available, the first task of the subcommittee was to prepare a metric practice guide. The 1st edition was issued in 1975. Improvements suggested by readers and users resulted in revisions in 1980, 1989, and 1998. This 5th edition reflects the current "state of the art" in metric practice for the U.S. welding industry and will assist the welding industry in converting to SI units and promote their voluntary use.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A1 Committee on Metric Practice, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society (see Annex G). A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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Metric Practice Guide for the Welding Industry

1. Scope

This metric practice guide is based on the International System of Units (SI) as defined in the *U.S. Federal Register* notice of July 28, 1998, "Metric System of Measurement: Interpretation of the International System of Units for the United States." (Other source documents and style guides are referenced in Annex D.) This guide contains specifications of the SI base units, derived units, prefixes, and rules for their use in AWS documents and by the welding industry. It also contains factors and rules for converting from inch-pound units (often referred to as U.S. Customary Units) to SI Units and recommendations to industry for managing the transition.

2. The International System of Units (SI)

A system of units is any collection of related units. SI is the only system that has the properties outlined in 2.1–2.3.

2.1 Completeness. Completeness requires that a unit of measurement be defined for every quantity of interest in the physical sciences and technologies.

2.2 Coherence. Coherence requires that all derived units in the system be obtained from the base units by the rules of multiplication and division with no numerical factor other than the number one (1) ever occurring in the expressions for derived units in terms of the base units. The system of units must also be coherent with its corresponding system of quantities and equations. A system of units is coherent with respect to a system of quantities and equations if the system of units is chosen in such a way that the equations between numerical values have exactly the same form (including numerical factors) as the corresponding equations between quantities.

Quantity	Derived Unit	Unit Equation
Force (mass times acceleration) $F = m \cdot a$	newton	$1\ N = 1\ kg \cdot m/s^2$
Energy (force times distance) $E = F \cdot l$	joule	$1\ J = 1\ N \cdot m$
Power (rate of energy transfer) $P = E/t$	watt	$1\ W = 1\ J/s$
Pressure (force divided by area) $p = F/A$	pascal	$1\ Pa = 1\ N/m^2$

2.3 Uniqueness. Uniqueness requires that there be one, and only one, unit defined for each quantity. For example, the SI Units for force (newton), energy (joule), and power (watt) are the same, respectively, whether the process is mechanical, electrical, or thermal.

2.4 Advantages of the SI. The International System of Units (SI) is the metric system of units in its latest form. SI is the only system of units which fully satisfies all the above three requirements for completeness, coherence, and uniqueness. Within SI, a set of base-ten prefixes is defined to form decimal multiples and submultiples of SI Units. SI Units and their base-ten multiples and submultiples are in harmony with our decimal system of arithmetic, facilitating easy numerical calculations. Awkward manipulations of common fractions such as 1/16, 1/32, and 1/64 are completely unnecessary. All industrial nations, including the United States by the Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418), have chosen the SI as the preferred system of units for all applications in science, engineering, technology, commerce, and trade.

3. SI Units and Symbols

SI consists of seven base units, derived units, and a set of prefixes for the formation of multiples of the various units.

3.1 SI Base Units. Names of SI base quantities, names of corresponding SI base units, their symbols, and definitions are given in Table 1.

3.2 SI Derived Units. SI derived units are formed as described in 2.2. Some of them have been given special names and symbols. Examples are listed in Table 2.

3.3 Prefixes. SI prefixes may be used to indicate multiples of SI Units, thus simplifying numeric terms and providing a convenient substitute for writing powers of ten as generally preferred in computation. For example, 16 800 meters or 16.8×10^3 meters becomes 16.8 kilometers. See Table 3 for the list of prefixes and 6.1 for examples of their use. The kilogram is the only SI base or derived unit whose name, for historical reasons, contains a prefix. In this case, the appropriate prefix is attached to gram.

4. Other Units Used with SI

There are certain units, although not part of SI, that are in widespread use and are acceptable for use with SI. See Table 4 for examples.

5. Units Pertaining to Welding

Table 5 lists the recommended SI multiples to be used in welding nomenclature. The selection of these terms was based on use of (1) SI Units where practicable, (2) numbers of reasonable size, and (3) accepted units currently in use.

Filler metal and fillet sizes are tabulated in Tables 6 and 7. SI values are approximate equivalents for conversion on drawings, specifications, and so forth. These values are for conversion only and are not intended for new designs where a more rational series for sizing, such as shown in the Rational Series column of Table 7, may be used.

6. Style and Usage

6.1 Application and Usage of Prefixes

6.1.1 Prefixes may be used with SI Units to indicate multiples. Prefixes provide convenient substitutes for using powers of ten and they eliminate nonsignificant digits.

Preferred	Acceptable
12.3 km	12 300 m, 12.3×10^3 m

Table 1
SI Base Units

Base Quantity	Unit Name	Unit Symbol	Definition
length	meter	m	The meter is the length of the path traveled by light in a vacuum during a time interval of 1/299 792 458 of a second.
mass	kilogram	kg	The mass equal to the mass of the international prototype of the kilogram.
time	second	s	The duration equal to 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.
electrical current	ampere	A	That constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed one meter apart in a vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length.
thermodynamic temperature	kelvin	K	The thermodynamic temperature that is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
luminous intensity	candela	cd	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.
amount of substance	mole	mol	The amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kilograms of carbon-12. Note: When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

Table 2
Examples of SI Derived Units

Derived Quantity	Unit Name	Unit Symbol	Expression in Terms of Other SI Units	Expression in Terms of SI Base Units
acceleration	meter per second squared			$m \cdot s^{-2}$
amount-of-substance concentration (concentration)	mole per cubic meter			$mol \cdot m^{-3}$
angular acceleration	radian per second squared		rad/s^2	$m \cdot m^{-1} \cdot s^{-2} = s^{-2}$
angular velocity	radian per second		rad/s	$m \cdot m^{-1} \cdot s^{-1} = s^{-1}$
area	square meter			m^2
capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
Celsius temperature	degree Celsius	°C		K
current density	ampere per square meter			$A \cdot m^{-2}$
dynamic viscosity	pascal second		Pa·s	$m^{-1} \cdot kg \cdot s^{-1}$
electric charge density	coulomb per cubic meter		C/m^3	$m^{-3} \cdot s \cdot A$
electric charge, quantity of electricity	coulomb	C		s·A
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
electric field strength	volt per meter		V/m	$m \cdot kg \cdot s^{-3} \cdot A^{-1}$
electric flux density	coulomb per square meter		C/m^2	$m^{-2} \cdot s \cdot A$
electric potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
energy density	joule per cubic meter		J/m^3	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	N·m	$m^2 \cdot kg \cdot s^{-2}$
exposure (X and γ rays)	coulomb per kilogram		C/kg	$kg^{-1} \cdot s \cdot A$
force	newton	N		$m \cdot kg \cdot s^{-2}$
frequency	hertz	Hz		s^{-1}
heat capacity, entropy	joule per kelvin		J/K	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$
heat flux density, irradiance	watt per square meter		W/m^2	$kg \cdot s^{-3}$
illuminance	lux	lx	lm/m^2	$m^2 \cdot m^{-4} \cdot cd = m^{-2} \cdot cd$
inductance	henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
luminance	candela per square meter			$cd \cdot m^{-2}$
luminous flux	lumen	lm	cd·sr	$m^2 \cdot m^{-2} \cdot cd = cd$
magnetic field strength	ampere per meter			$A \cdot m^{-1}$
magnetic flux	weber	Wb	V·s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$

(continued)

Table 2 (Continued)

Derived Quantity	Unit Name	Unit Symbol	Expression in Terms of Other SI Units	Expression in Terms of SI Base Units
mass density (density)	kilogram per cubic meter			$kg \cdot m^{-3}$
mass fraction	kilogram per kilogram, which may be represented by the number 1			$kg \cdot kg^{-1} = 1$
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)	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1} \cdot mol^{-1}$
moment of force	newton meter		N·m	$m^2 \cdot kg \cdot s^{-2}$
permeability	henry per meter		H/m	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$
permittivity	farad per meter		F/m	$m^{-3} \cdot kg^{-1} \cdot s^4 \cdot A^2$
plane angle	radian	rad		$m \cdot m^{-1} = 1$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
solid angle	steradian	sr		$m^2 \cdot m^{-2} = 1$
specific energy	joule per kilogram		J/kg	$m^2 \cdot s^{-2}$
specific heat capacity, specific entropy	joule per kilogram kelvin		J/(kg·K)	$m^2 \cdot s^{-2} \cdot K^{-1}$
specific volume	cubic meter per kilogram			$m^3 \cdot kg^{-1}$
speed, velocity	meter per second			$m \cdot s^{-1}$
surface tension	newton per meter		N/m	$kg \cdot s^{-2}$
thermal conductivity	watt per meter kelvin		W/(m·K)	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$
volume	cubic meter			m^3
wave number	reciprocal meter			m^{-1}

Table 3
SI Prefixes

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

Table 4
Other Units Which May be Used with SI Units

Units	Symbol	Value
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3600 s
day	d	1 d = 24 h = 1440 min = 86 400 s
degree (angular)	°	1° = (π/180) rad = 0.0175 rad
liter	L	1 L = 0.001 m^3 = 1 dm^3
metric ton	t	1 t = 1000 kg

Table 5
Units Pertaining to Welding

Quantity	SI Units or Multiples	Symbol
area dimensions	square millimeter	mm^2
current density	ampere per square millimeter	A/mm^2
deposition rate	kilogram per hour	kg/h
electrical resistivity	ohm meter	Ω·m
electrode force	newton	N
flow rate (gas and liquid)	liter per minute	L/min
fracture toughness	meganewton meter$^{-3/2}$	$MN{\cdot}m^{-3/2}$
impact energy absorption	joule	J = N·m
linear dimensions	millimeter	mm
moment of force (torque)	newton meter	N·m
power density	watt per square meter	W/m^2
pressure (gas and liquid)	kilopascal	$kPa = 1000\ N/m^2$
pressure (vacuum)	pascal	$Pa = N/m^2$
tensile strength	megapascal	$MPa = 1\ 000\ 000\ N/m^2$
thermal conductivity	watt per meter kelvin	W/(m·K)
travel speed	millimeter per second	mm/s
volume dimensions	cubic millimeter	mm^3
wire feed speed	millimeter per second	mm/s

6.1.2 Prefixes in steps of 1000 are recommended. It is generally desirable to avoid the prefixes hecto, deka, deci, and centi in technical writing for the welding industry.

Preferred	Nonpreferred
mm, m, km	hm, dam, dm, cm

6.1.3 It is generally desirable that the prefix chosen place the numerical value between 0.1 and 1000. For special situations, such as tabular presentations, however, this recommendation may be inappropriate.

6.1.4 Multiple and hyphenated prefixes shall not be used.

Correct	Incorrect
pF, Gg, GW	μμF, Mkg, kMW, G-W

6.1.5 It is generally desirable to use only base and derived units in the denominator. Prefixes are used with the numerator unit to give numbers of appropriate size (see 6.1.3).

Preferred	Nonpreferred
200 J/kg 1 Mg/m 1 MPa, 1 MN/m^2	0.2 J/g 1 kg/mm 1 N/mm^2

6.1.6 Prefixes should not be mixed unless magnitudes warrant a difference.

Preferred	Nonpreferred
5 mm long × 10 mm high	5 mm long × 0.01 m high

Exception
4 mm diameter × 50 m long

6.1.7 The pronunciation of the prefixes is always the same, regardless of the following unit name. For example, the accepted pronunciation for kilo is "KILL-oh." The slang expression *keelo* for kilogram should never be used.

6.2 Mass, Force, and Weight. In SI, the unit of mass is the kilogram (kg), and the unit of force is the newton (N). In common and everyday use, and especially in common parlance, the term *weight* is usually used as a synonym for *mass*. As a measure of mass, *weight* should be restricted to commercial usage. (See Annex F for a discussion of the terms *mass* and *force* as it relates to the term *weight* in paragraph F4.)

Correct	Incorrect
N/m^2 or Pa, N·m/s or W	kgf/m^2

6.3 Temperature. The SI Unit for thermodynamic temperature is the kelvin. The SI Unit for Celsius temperature,

Table 6
Filler Metal Sizes

Fractional in	Decimal Equivalents, in(1)	ISO 544(2) mm
	0.020	**0.5**
	0.024	**0.6**
	0.025	
	0.030	
	0.031	**0.8**
	0.035	**0.9**
	0.039	**1.0**
	0.045	
3/64	0.047	1.2
	0.052	1.3
	0.055	1.4
	0.060	
1/16	0.062	1.6
	0.068	1.7
	0.071	1.8
5/64	0.078	2.0
3/32	0.094	2.4
	0.098	2.5
	0.110	2.8
	0.118	3.0
	0.120	
1/8	0.125	3.2
5/32	0.156	4.0
3/16	0.188	4.8
	0.197	5.0
7/32	0.219	5.6
	0.236	6.0
1/4	0.250	6.4
5/16	0.313	8.0

Notes:
(1) Shaded values not normally used in AWS specifications.
(2) International Organization for Standardization (ISO), Forthcoming, *Technical Delivery Conditions for Welding Filler Metals—Type of Product, Dimensions, and Marking*. ISO 544, Geneva: International Organization for Standardization. Bolded items normally in bare wire only. Shaded items are nonstandard.

Table 7
Fillet Sizes

Approximate Equivalents		Rational Series
in	mm	mm
1/8	3	3
5/32	4	4
3/16	5	5
1/4	6	6
5/16	8	8
3/8	10	10
7/16	11	12
1/2	13	[Note (1)]
5/8	16	16
3/4	19	20
1	25	25

Note:
(1) No value is required in this interval for rational sizing. See the 10 series in Table 12, and the example given in 9.2.

used in most common applications, is the degree Celsius. The degree Celsius was formerly called "degree centigrade." The degree Fahrenheit should not be used.

6.4 Time. The SI Unit for time is the second. The use of minute, hour, and day, which are non-SI Units, is permissible.

6.5 Angles. The SI Unit for plane angle is the radian. The SI Unit for solid angle is the steradian. The degree (°) may be used where appropriate or convenient and should be decimalized. Angular minutes and seconds should be avoided.

Preferred	Nonpreferred
5.1425°	5°8'33"

6.6 Stress and Pressure. The SI Unit for pressure and stress is the pascal, which is the special name given to the newton per square meter. A multiple of the pascal, the kilopascal, is appropriate for most pressures encountered in welding practice, and the megapascal for most stresses. Other units for pressure and stress, such as the following, should not be used.

Correct	Incorrect
N/m^2, Pa, kPa, MPa	kgf/cm^2, psi

6.7 Capitalization. SI Unit names are capitalized only at the beginning of a sentence (examples: newton, pascal, meter, kelvin, and hertz). Exception: Celsius in "degree Celsius," is always capitalized.

SI Unit symbols are not capitalized except for those derived from a proper name (examples: A for ampere; J for joule; K for kelvin; N for newton; Pa for pascal; and W for watt). Although both lowercase "l' and the capital "L" are internationally accepted symbols for the liter, to avoid risk of confusion the preferred symbol for the use in the United States is "L."

Only seven prefix symbols are capitalized, namely, Y for yotta; Z for zetta; E for exa; P for peta; T for tera; G for giga; and M for mega.

6.8 Plurals. Unit symbols are the same for singular and plural. Unit names form their plurals in the usual manner.

Correct	Incorrect
50 newtons	50 newton
50 N	50 Ns
25 grams	25 gram
25 g	25 gs
22 kelvins	22 kelvin
22 K	22 Ks

6.9 Punctuation. Periods are not to be used after unit symbols except at the end of a sentence.

Periods are not used in unit symbols or in conjunction with prefixes.

Correct	Incorrect
5.7 mm	5.7 m.m., 5.7 mm.

A raised dot is used to indicate the product of two unit symbols. A space should be used to indicate the product of two unit names.

Preferred	Nonpreferred	Incorrect
newton meter (N·m)	newton-meter (N m)	newton·meter (N-m)

Symbols for derived units involving division may use a slanted line (solidus), horizontal line, or negative exponents to indicate the division.

(1) No more than one solidus may be used in any unit combination unless parentheses are used to provide clarity and to prevent ambiguity.

(2) In complicated cases, the use of negative exponents may be preferable to the use of the solidus (whether with or without parentheses).

(3) Numerical values should be adjusted so that the numerical value of the denominator is one.

Correct	Incorrect
m/s, m·s–1, 4 m/s m/s2, m·kg/(s3·A)	m/0.1 s, m/s/s m·kg/s3/A, kg/s/m2

The word "per" is used to indicate the quotient of two unit names.

Example: meter per second squared (m/s^2)

An exponent is used with unit symbols to show powers.

Example: m^3

The words "square," "squared," and "cubic" are used with unit names to indicate powers.

Example: square meter (m^2), cubic meter (m^3), and second squared (s^2)

6.10 Writing Numbers

6.10.1 Periods (not commas) are used as decimal markers.

6.10.2 Numbers made up of five or more digits should be written with a space separating each group of three digits counting both to the left and right of the decimal point. With four digit numbers, the spacing is optional.

6.10.3 Spaces (not commas) should be used between the groups of three digits.

Correct	Incorrect
1 420 462.1 0.045 62 1452 or 1 452	1,420,462.1 0.04562 1,452

6.11 Miscellaneous Styling

6.11.1 A space is to be used between the numerical value and the unit symbol.

Correct	Incorrect
4 mm	4mm

6.11.2 Unit symbols and names are never used together in a single expression:

Correct	Incorrect
meter per second (m/s)	meter/s

6.11.3 Numbers are expressed as decimals, not as fractions. The decimal should be preceded by a zero when the number is less than unity.

Correct	Incorrect
0.5 kg, 1.75 m	1/2 kg, .5 kg., 1 3/4 m

6.11.4 Symbols for SI Units are printed in roman (upright) type. Symbols for quantities are preferably printed in italic (slanted) type.

Correct	Nonpreferred	Incorrect
V = 87 V *I* = 14 A *T* = 200°C	V = 87 V I = 14 A T = 200°C	V = 87 *V* I = 14 *A* T = 200°*C*

6.11.5 There are two exceptions to the use of Latin alphabetic characters for SI symbols: the symbol "µ" for the prefix micro and the symbol "Ω" for the unit ohm. If circumstances prevent using these Greek letters, then use u as the symbol for micro and Ohm as the symbol for ohm. Do not hand draw a tail on the u; leave it as typewritten. Use an uppercase O in Ohm when it is used as a symbol but not when used as a word, since it is named after a person.

Acceptable	Incorrect
4 um	4 microns
25 Ohm	25 Ohms
25 ohms	25 Ohms
17 Ohm/m	17 ohm/m, 17 Ohm/meter
17 ohms per meter	17 Ohm per meter

6.11.6 When it is necessary or desirable to use inch-pound units in an equation or table, SI Units should be restated in a separate equation, table, or column in a table. As an alternative, a note may be added to an equation or table giving the factors to be used in converting the calculated result in inch-pound to preferred SI Units. The SI equivalents may follow and be inserted in parentheses or brackets.

7. Conversions

When converting units from inch-pound to SI Units, one way is to apply the conversion factors in Tables 8 or 9, and make use of the rounding rules discussed in the following sections. Another way is to apply preferred SI values, often those that prevail in countries whose measurements have long been in metric units, or appear in international standards (see Table 6). The application of SI values is often guided by the use of preferred numbers to facilitate standardization (see Section 9). In the first case, the strictly mathematical conversions are said to be "soft" conversions. Applying preferred SI values for conversion has been termed "hard" conversions. Such terms have been misleading and are gradually losing favor when discussing conversion methods.

When providing SI Units to correspond to inch-pound units in AWS documents and technical publications of other societies, the use of SI values are generally shown to follow the inch-pound units in brackets, for example 70 ksi [480 MPa]. For the so-called "soft" conversion, the practice for showing the "exact" SI values is in parentheses, as 70 ksi (483 MPa). Note that the so-called "hard" conversions are not exact, and judgment must be applied especially where parts or components must fit, such as for filler metals requiring close contact when feeding through nozzles. The solution to the inexactness of the conversion can be accommodated by establishing tolerance ranges which overlap, allowing manufacturers to offer standard products that are sized to accommodate both SI and U.S. inch-pound usage.

7.1 Rules for Converting and Rounding. Converting and rounding are necessary only during a transition period. In manufacturing practice, this occurs most frequently when designing is done in SI Units and fabrication must be done in conventional units. The necessity for conversion and rounding disappears when all steps can be done in one system.

Exact conversion from one system to another usually results in numbers that are inconvenient to use. Also, the intended precision is exaggerated when the conversion results in more decimal places than are necessary.

The degree of accuracy of the converted number is based on the intended or necessary precision of the product. The precision must be determined by the designer or user. The guidelines given herein may then be applied to arrive at appropriate numerical equivalents.

7.2 Inch to Millimeter Conversion. Exact conversion from inches to millimeters often results in unnecessarily long decimal numbers. Showing more decimal places than necessary leads to misinterpretation, uses valuable space, and increases the possibility of error. The numbers should be rounded to eliminate insignificant decimal places, consistent with the accuracy required. The rounding of equivalent millimeter dimensions should be handled as described here.

7.2.1 Nominal Dimensions. The closest practical indication of equivalent inch and millimeter values occurs when the millimeter value is shown to one less decimal place than its inch equivalent. For example, 0.365 in equals 9.27 mm. However, fractional inch conversions may exaggerate the intended precision. For example, the rule may not be applicable when changing 1-7/8 in to 47.63 mm unless the precision of 1-7/8 in was intended to be that of 1.875 inch. Some dimensions must be converted more accurately to ensure interchangeability of parts. The methods described in 7.3 will accomplish this requirement.

7.2.2 Tolerances. The following round-off criteria should be used when it is necessary to ensure the physical and functional interchangeability of parts made and inspected using either system of measurement, and when inch dimensions are converted to millimeter equivalents and shown on dual dimensioned drawings:

(1) *Basic and maximum-minimum dimensions.* Basic dimensions are inherently precise and should be converted exactly. When the function of a feature requires that the maximum and minimum limits in millimeters be within the inch limits, maximum limits are rounded down and minimum limits are rounded up.

(2) *Dimensions without tolerance.* Untoleranced dimensions are converted to exact millimeter equivalents and rounded to equivalent or better precision, depending upon the purpose of the dimension.

(3) *Toleranced dimensions.* The normal practice for toleranced dimensions is to use Method A as described in 7.2.2.2. However, when the function of a feature requires that the millimeter equivalents must be within the inch

Table 8
General Conversions

Quantity	To Convert From	To	Multiply By
acceleration (angular)	revolution per minute squared	rad/s^2	$1.745\ 329 \times 10^{-3}$
acceleration (linear)	in/min^2	m/s^2	$7.055\ 556 \times 10^{-6}$
	ft/min^2	m/s^2	$8.466\ 667 \times 10^{-5}$
	in/min^2	mm/s^2	$7.055\ 556 \times 10^{-3}$
	ft/s^2	m/s^2	$3.048\ 000 \times 10^{-1}$
angle, plane	deg	rad	$1.745\ 329 \times 10^{-2}$
	minute	rad	$2.908\ 882 \times 10^{-4}$
	second	rad	$4.848\ 137 \times 10^{-6}$
area	in^2	m^2	$6.451\ 600 \times 10^{-4}$
	ft^2	m^2	$9.290\ 304 \times 10^{-2}$
	yd^2	m^2	$8.361\ 274 \times 10^{-1}$
	in^2	mm^2	$6.451\ 600 \times 10^{2}$
	ft^2	mm^2	$9.290\ 304 \times 10^{4}$
	acre (U.S. Survey)	m^2	$4.046\ 873 \times 10^{3}$
density	pound per cubic inch	kg/m^3	$2.767\ 990 \times 10^{4}$
	pound per cubic foot	kg/m^3	$1.601\ 846 \times 10$
energy, work, heat, and impact energy	foot pound-force	J	1.355 818
	foot poundal	J	$4.214\ 011 \times 10^{-2}$
	Btu*	J	$1.055\ 056 \times 10^{3}$
	calorie*	J	4.186 800
	watt hour	J	$3.600\ 000 \times 10^{3}$
force	kilogram-force	N	9.806 650
	pound-force	N	4.448 222
impact strength	(see energy)		
length	in	m	$2.540\ 000 \times 10^{-2}$
	ft	m	$3.048\ 000 \times 10^{-1}$
	yd	m	$9.144\ 000 \times 10^{-1}$
	mile (statute)	m	$1.609\ 344 \times 10^{3}$
mass	pound (avdp)	kg	$4.535\ 924 \times 10^{-1}$
	metric ton	kg	$1.000\ 000 \times 10^{3}$
	ton (short, 2000 lb)	kg	$9.071\ 847 \times 10^{2}$
	slug	kg	$1.459\ 390 \times 10$
power	horsepower (550 ft·lbf/s)	W	$7.456\ 999 \times 10^{2}$
	horsepower (electric)	W	$7.460\ 000 \times 10^{2}$
	Btu/h*	W	$2.930\ 711 \times 10^{-1}$
	calorie per minute*	W	$6.976\ 333 \times 10^{-2}$
	foot pound-force per minute	W	$2.259\ 697 \times 10^{-2}$
pressure	psi	kPa	6.894 757
	bar	kPa	$1.000\ 000 \times 10^{2}$
	atmosphere	kPa	$1.013\ 250 \times 10^{2}$
	kip/in^2	kPa	$6.894\ 757 \times 10^{3}$
temperature	degree Celsius	K	$T_K = t_C + 273.15$
	degree Fahrenheit	K	$T_K = (t_F + 459.67)/1.8$
	degree Rankine	K	$T_K = T_R/1.8$
	degree Fahrenheit	°C	$t_C = (t_F - 32)/1.8$
	kelvin	°C	$t_C = T_K - 273.15$
temperature interval	degree Fahrenheit	K	0.555 555 6
	degree Rankine	K	0.555 555 6
	degree Fahrenheit	°C	0.555 555 6
tensile strength (stress)	ksi	MPa	6.894 757
torque	pound-force inch	N·m	$1.129\ 848 \times 10^{-1}$
	pound-force foot	N·m	1.355 818

Table 8
General Conversions

Quantity	To Convert From	To	Multiply By
velocity (angular)	revolution per minute	rad/s	$1.047\ 198 \times 10^{-1}$
	degree per minute	rad/s	$2.908\ 882 \times 10^{-4}$
	revolution per minute	deg/min	$3.600\ 000 \times 10^{2}$
velocity (linear)	in/min	m/s	$4.233\ 333 \times 10^{-4}$
	ft/min	m/s	$5.080\ 000 \times 10^{-3}$
	in/min	mm/s	$4.233\ 333 \times 10^{-1}$
	ft/min	mm/s	5.080 000
	mi/h	km/h	1.609 344
volume	in^3	m^3	$1.638\ 706 \times 10^{-5}$
	ft^3	m^3	$2.831\ 685 \times 10^{-2}$
	yd^3	m^3	$7.645\ 549 \times 10^{-1}$
	in^3	mm^3	$1.638\ 706 \times 10^{4}$
	ft^3	mm^3	$2.831\ 685 \times 10^{7}$
	in^3	L	$1.683\ 706 \times 10^{-2}$
	ft^3	L	$2.831\ 685 \times 10$
	gallon (U.S.)	L	3.785 412

*thermochemical

Table 9
Conversions for Common Welding Terms

Quantity	To Convert From	To	Multiply By
area dimensions	in^2	mm^2	$6.451\ 600 \times 10^{2}$
current density	A/in^2	A/mm^2	$1.550\ 003 \times 10^{-3}$
deposition rate	lb/h	kg/h	$4.535\ 924 \times 10^{-1}$
electrical resistivity	Ω·cm	Ω·m	$1.000\ 000 \times 10^{-2}$
flow rate	ft^3/h	L/min	$4.719\ 474 \times 10^{-1}$
	gallon per hour	L/min	$6.309\ 020 \times 10^{-2}$
	gallon per minute	L/min	3.785 412
fracture toughness	$ksi \cdot in^{1/2}$	$MN \cdot m^{-3/2}$	1.098 843
	$ksi \cdot in^{1/2}$	$MPa \cdot m^{1/2}$	1.098 843
heat input	J/in	J/m	$3.937\ 008 \times 10$
impact energy absorption	foot pound-force	J	1.355 818
linear measurements	in	mm	$2.540\ 000 \times 10$
	ft	mm	$3.048\ 000 \times 10^{2}$
power density	W/in^2	W/m^2	$1.550\ 003 \times 10^{3}$
pressure (gas and liquid)	psi	kPa	6.894 757
	lbf/ft^2	kPa	$4.788\ 026 \times 10^{-2}$
	N/mm^2	kPa	$1.000\ 000 \times 10^{3}$
pressure (vacuum)	torr (mm Hg at 0°C)	Pa	$1.333\ 224\ 10^{2}$
	micron (µm Hg at 0°C)	Pa	$1.333\ 224 \times 10^{-1}$
tensile strength	psi	MPa	$6.894\ 757 \times 10^{-3}$
	lbf/ft^2	MPa	$4.788\ 026 \times 10^{-5}$
	N/mm^2	MPa	1.000 000
thermal conductivity	cal/(cm·s·°C)	W/(m·K)	$4.184\ 000 \times 10^{2}$
travel speed, wire feed speed	in/min	mm/s	$4.233\ 333 \times 10^{-1}$

dimension tolerance limits in all cases, Method B is used as described in 7.2.2.3.

7.2.2.1 Number of Decimal Places in Tolerances. Table 10 lists the criteria for retaining decimal places in millimeter equivalents to inch tolerances. The number of decimal places is determined by the inch tolerance span.

7.2.2.2 Round-Off Method A. This method produces rounded millimeter tolerances which will not vary from the inch tolerances by more than five percent. Thus, for a dimension with a tolerance of 0.001 inch, the maximum amount that the rounded millimeter can be greater or less than the inch tolerances is 0.000 050 inch.

To determine the millimeter equivalents of inch dimensions by Method A, these steps should be followed:

(1) The maximum and minimum limits in inches should be determined.

(2) The tolerance span in inches should be determined.

(3) The inch limit dimensions should be converted to millimeter values using exact millimeter equivalents.

(4) Based on the tolerance span in inches, the number of decimal places to be retained should be established using Table 10 and the millimeter values rounded according to the rounding rules given in 7.4. See the example in Table 11.

Table 10
Millimeter Value Round-Off Using Inch Tolerance Span

Inch Tolerance Span		Round-Off Millimeter Value to These Decimal Places	
At Least	Less Than		
0.000 04	0.0004	4 places	0.00XX
0.0004	0.004	3 places	0.0XX
0.004	0.04	2 places	0.XX
0.04	0.4	1 place	X.X
0.4 and over		Whole number	XX

Example: The span of a +0.005 to –0.003 in tolerance is 0.008. Since 0.008 is between 0.004 and 0.04, two decimal places are retained in individually converting 0.005 and 0.003.

7.2.2.3 Round-Off Method B. This method is used when the resulting millimeter tolerances must be within the inch tolerances. In extreme cases, this method may result in the lower limit millimeter tolerance being greater than the lower inch tolerance by a maximum of 5%. Similarly, the upper limit millimeter tolerance may be smaller than the upper inch tolerance by a maximum of 5%. Thus, the tolerance span may be reduced by up to 10% of the original design inch tolerance; however, it is very unlikely that the 5% maximum will occur at both limits simultaneously. To determine the millimeter equivalents of inch dimensions by method B, these steps should be followed:

Table 11
Comparison of Round-Off Methods A and B

Inch dimension:	1.934 in–1.966 in
Tolerance span:	0.032 in
Conversion:	1.934 in = 49.1236 mm (exactly) 1.966 in = 49.9364 mm (exactly)
From Table 10:	0.032 lies between 0.004 and 0.04; therefore, the millimeter values are to be rounded to two decimal places.
Method A:	Rounding off 49.1236 and 49.9364 to two decimal places via the method shown in 7.2.3 gives 49.12 mm and 49.94 mm, respectively. Method A gives a tolerance span of 0.82 mm.
Method B:	Rounding to within the inch tolerance limits requires the 49.1236 mm limit to be rounded up, giving 49.13 mm as the lower limit, and the 49.9364 mm limit to be rounded down, giving 49.93 mm as the upper limit. Method B gives a tolerance span of 0.80 mm.

General Note: The tolerance span of 0.32 inch equals 0.8128 mm. In this example, Method A would increase the tolerance span of 0.0072 mm (0.88%); whereas, Method B would decrease the tolerance span by 0.0128 mm (1.6%).

(1) The maximum and minimum limits in inches should be determined.

(2) The tolerance span in inches should be determined.

(3) The inch tolerance should be converted to exact millimeter equivalents.

(4) Based on the tolerance span in inches, the number of decimal places to be retained in the millimeter values should be established using Table 10.

(5) If rounding is required, millimeter values should be rounded to fall within the inch tolerance limits; that is, to the next lower value for the upper limit and to the next higher value for the lower limit (see the example in Table 11).

7.3 Other Conversions. To establish meaningful and equivalent converted values, a careful determination must be made of the number of significant digits to be retained so as not to sacrifice or exaggerate the precision of the value. To convert a pressure of 1000 psi to 6.894 757 MPa is not practical because the value does not warrant expressing the conversion using six decimal places. Applying the policy of 7.3.4, a practical conversion is 7 MPa. The intended precision of a value can be established from the specified tolerance or by an understanding of the equipment, process, or accuracy of the measuring device.

7.3.1 Values with a Specified Tolerance. A tolerance on a value provides a good indication of the intended precision. A general rule for determining the intended precision of a toleranced value is to assume that it is one-tenth of the total tolerance. Because the intended precision of the converted value should be no greater than that of the original, the total tolerance is divided by ten and converted. The proper significant digits are retained in both the converted value and the converted tolerance so that the last significant digit retained is in units no larger than one-tenth the converted tolerance. The following examples illustrate this rule:

(1) 200 ± 15 psi pressure converted to Pa. Total tolerance is 30 psi, divided by 10 is 3 psi, which converted is about 20.7 kPa. The units to use equal 10 kPa (rather than 1 kPa or 100 kPa) because 10 kPa is the largest unit smaller than 20.7 kPa, which is one-tenth the converted tolerance.

200 ± 15 psi = 1378.9514 ± 103.421 355 kPa, which rounds to 1380 ± 100 kPa = 1.38 ± 0.10 MPa.

(2) 25 ± 0.1 oz of alcohol converted to liters. Total tolerance is 0.2 oz, divided by 10 is 0.02 oz, converted is about 0.6 mL.

Units to use: 0.1 mL (rather than 10 mL or 1 mL).

25 ± 0.1 oz = 739.34 ± 2.8957 mL, which rounds to 739.3 ± 2.9 mL.

7.3.2 Values with No Specified Tolerance. If a value is shown without a tolerance, the intended precision relates to the number of significant digits shown by assuming that the value had been rounded from a greater number of digits. The intended precision is established as being plus or minus one-half unit of the last significant digit in which the value is stated. However, as the last significant digit moves away from the decimal point, the intended precision becomes distorted if this rule is used indiscriminately. In these cases, the intended precision is estimated as being some digit closer to the decimal point based on the nature of the value's use. Because the intended precision of the converted value should be no greater than that of the original, the intended precision is established and converted. The proper significant digits are retained in the converted value so that the last significant digit retained is in units no larger than the converted intended precision. The following examples illustrate this policy:

(1) 157 miles (rounded from any value between 156.5 and 157.5 miles) to kilometers. Total intended precision is 1 mile, which is about 1.6 km.

Units to use: 1 km

157 miles = 252.613 km, which rounds to 253 km.

(2) 50 000 psi tensile strength converted to pascals. Total estimated precision is 500 psi (3.4 MPa) from the nature of use and the precision of the measuring equipment.

Units to use: 1 MPa

50 000 psi = 344.7379 MPa which rounds to 345 MPa.

(See also 7.3.4 for less precise conversion.)

(3) An electrical lead 8 ft long, converted to meters. The total intended precision is 1 ft, or about 0.3 m.

Units to use: 0.1 m

8 ft = 2.4384 m, which rounds to 2.4 m.

7.3.3 Temperature. All temperatures expressed in whole numbers of degrees Fahrenheit are converted to the nearest 0.1 kelvin or degree Celsius. Fahrenheit temperatures indicated to be approximate, maximum, or minimum, or to have a tolerance of ± 5°F or more, are converted to the nearest whole number in kelvins or degrees Celsius. Fahrenheit temperatures having a tolerance of plus or minus 100°F or more are converted to the nearest 5 kelvins or degrees Celsius.

100 ± 5°F = 38 ± 3°C = 311 ± 3 K

1000 ± 100°F = 540 ± 55°C = 810 ± 55 K

7.3.4 Pressure or Stress Conversion. In most cases, stress values are converted from ksi to the nearest one megapascal. Pressure or stress values having an uncertainty of more than two percent may be converted without rounding by the approximate factors:

1 psi = 7 kPa   1 ksi = 7 MPa

7.4 Round-Off Rules. When the next digit beyond the last digit to be retained is less than five, the last digit retained is not changed.

4.463 25 rounded to three decimal places is 4.463.

7.4.1 When the digits beyond the last digit to be retained amount to more than five followed by zeros, the last digit retained is increased by one.

8.376 52 rounded to three decimal places is 8.377.

7.4.2 When the digit beyond the last digit to be retained is exactly five followed by zeros (expressed or implied), the last digit to be retained, if even, is unchanged; but the last digit to be retained, if odd, is increased by one.

4.365 00 becomes 4.36 when rounded to two decimal places.

4.355 00 also becomes 4.36 when rounded to two decimal places.

7.4.3 The final rounded value is obtained from the precise value to be rounded, not from a series of successive rounding. To maintain precision during conversion, the millimeter equivalent value is carried out to at least one extra decimal place. Generally, it is best to use exact values and round off only the final results.

8. Transition

8.1 Introduction. Almost all segments of U.S. society and industry will feel the impact of the metric conversion. Indeed, many companies are already in various phases of conversion. Some companies, particularly those with foreign interests, have completely converted. Others are maintaining an awareness of the state of metrication in the United States.

8.2 Considerations

8.2.1 Abrupt Changeover in Engineering and Design from Inch-Pound Units to Metric Units. The goal is to have engineers and designers "thinking metric" as quickly as possible. The experience in Great Britain showed that learning to think metric is important in reducing transition time and costs and in gaining the benefits of the simpler, more rational metric measurement system. This is especially so for engineers and designers who must think in groups of interrelated numbers and who depend on a "feel" for the design significance of these relationships. Changing engineering and design activities to metric abruptly is practical because it is largely a conversion involving relatively low-cost equipment replacement.

8.2.2 Replacement of Fabricating Equipment on a Cyclical Basis Except for Some Inspection Activities. Changing fabrication activities from inch-pound to SI Units involves a large capital investment in equipment. The transition time and cost in the shops can be shortened somewhat by converting machine displays. Some machines are used only for nonprecision stock removal and need never be converted. Others, such as the numerically controlled machines with digital displays, are electronically convertible. Inspection gages are in a special category. They last so long that cyclical replacement is not a practical way to convert inspection activities. Also, inspection serves as a check on the other fabrication activities, including conversion mistakes. It seems reasonable to convert gages on a high-priority basis.

Cost-benefit considerations in the shop call for more of a cyclical replacement approach with a completion goal consistent with average tool life. This means that the metric unit used by the engineering and design departments must be converted at the machine tool that still operates in inches. Metric-to-inch conversions must occur at some stage of the design-fabrication cycle while there are machines still working in inches.

8.2.3 Dual Dimensioning. A popular way to handle the conversion of measurement is to dual-dimension the drawings, but side-by-side dual dimensioning (using brackets) is a costly transition mechanism. Besides added drawing costs and increased drawing clutter, it allows engineers and designers to avoid learning to think metric because all the old familiar inch numbers are still there to use. Also, it is important for the transition period conversion mechanisms to allow for gradual change as the need for conversion in the shop decreases.

Dual dimensioning at the design level can make for a costly transition mechanism until the last machine or vendor that must be dealt with is converted. This is because the purchase-fabricate decision is usually made after design work is complete; the designers do not know where a drawing may go for fabrication and must treat every part as though it will be done by inch machines. One company considered several ideas and decided that the simplest and least costly way to handle the millimeter-inch conversion at the machine was to use a conversion table (see 8.2.4.1). This means there would be a dualism in the shop, decreasing with time, during the transition period. Dualism is less troublesome in shops where, for the most part, an operator is concerned with only one dimension at a time: the one being cut.

8.2.4 Engineering Drawing-to-Shop Practice Conversions. The following techniques may be considered for dimensioning drawings. They are to be used only during a transition period. Ultimately, all dimensions will be in SI Units, and all machine tools will have similar displays.

The first method involves the use of a conversion table which accompanies each drawing or is otherwise available to each user of the drawing. The second method involves the inclusion of inch equivalents of millimeter dimensions, in tabular form, on each drawing.

Note that neither method involves side-by-side dual dimensioning.

8.2.4.1 Technique No. 1: The Use of a One-Page Simplified Conversion Table Based on Preferred Dimensions. Supplying a conversion table to the machine operator becomes a more attractive idea if it is combined with a system of preferred dimensions and tolerances that permits a simplified one-page table. Designers are expected to use the preferred numbers for dimensions and tolerances except in unusual cases. Since both designers and fabricators use the same simplified table, the engineer/designer should have confidence in the conversion of the millimeter dimension for fabrication and inspection. The few numbers on a drawing not covered by the table are converted by the designer and placed in a corner of the drawing. The success of this approach is measured by how few numbers on a drawing are not from the preferred list. If too many of the numbers on a drawing are converted on the drawing, it becomes a form of dual dimensioning.

8.2.4.2 Technique No. 2: The Inclusion of a Conversion Chart on Each Drawing. Millimeter-to-inch conversions are included in tabular form on new drawings. Only the dimensions appearing on the drawing are given, usually in order of magnitude. One approach is to use computer-generated conversion charts which are copied onto adhesive-backed Mylar. The charts are then attached to the original drawings for copying. Similar charts can be attached to existing drawings vellums along with a prominent "METRIC" label. The "change" block would reflect the revision, and the drawings would be reissued.

8.2.5 When to Replace Existing Inch-Pound Inventory with Metric Inventory. No attempt should be made to use raw materials and supplies produced with metric units if doing so degrades some design or fabrication factor, including cost. Also, materials should be called out on metric drawings as they are fabricated and specified, i.e., metric units should be used for "metric" materials, and inch-pound units should be used to define materials fabricated using inch-pound units. The entire inventory of supplies should be monitored to introduce metric supplies on a timely basis. Also, it is important to know as early as possible the availability of metric materials to prepare for the change in inventory and design.

8.2.6 The Use of a Preferred Number Approach for General Inventory Reduction Prior to the Need to Carry Dual Inventory. A possible inventory reduction plan would designate preferred items within the existing inventory to the engineering and design departments. Item usage would then be monitored to see which, if any, of the nonpreferred items should be added to the preferred list. All remaining nonpreferred items would be eliminated from the inventory. It is important that the monitoring procedure be sensitive to the possible use of preferred items at the expense of design integrity. The attractiveness of the preferred list approach to inventory reduction is that design requirements can be tested before anyone has to take a hard position on what will be eliminated from the inventory (see section 9, Preferred Numbers).

The success of this approach depends upon the extent to which an existing inventory can be pruned without significant loss of fabrication efficiency.

8.2.7 Each Major Group Should Be Taught Only What It Needs to Know. Formal classroom training can provide changeover background information for inspirational purposes and for the basics of SI. Reference material should then be provided for self-teaching. There has been a tendency to overdo the training aspects of metric conversion beyond what is economical. SI is a simple system, and individuals need to learn initially only the part of SI which pertains to their discipline.

8.2.8 Standard Practices Should Be Established and Used. The necessary policy and procedures should be provided by the issuance of a metric engineering standard. This standard will serve to coordinate efforts and assure that common practices are used.

9. Preferred Numbers

9.1 Definition. Preferred numbers are a series of numbers recommended as an aid to establish sizes, such as sizes of bolts, electrodes, fillet welds, etc., where a range of sizes is desired.

These series are designed according to a geometric progression. Each number in the series has the same proportional relationship to its preceding number. For general purposes of sizing and grading, a geometric series is usually more rational than an arithmetically progressive series.

In an arithmetic series, the unit size increment is constant for any range of sizes. An example of the customary arithmetic progression is fractional drive (or hole) sizes that are in size increments of 1/64 inch. The fineness of the division gets ridiculously small as the nominal diameter increases to 1 inch or more.

9.2 Application of Preferred Numbers. The size of the increments in a geometric series is determined by a multiplying factor which, in the most common series used in the mechanical field (the Renard Series), is a root of 10. The 5, 10, 20, and 40 series are the most commonly used preferred number series. These cover the majority of applications. One series is selected from this group for a given standard, according to the size or number of increments desired.

The basis for the preferred number system is as follows: 1.0 is used as the first number of a series. Each succeeding number is determined by multiplying its preceding number by a constant factor for the series. The product is rounded to measurable values, consistent with the characteristics for which a standard is being established. Constant factors are determined as follows:

For the 5 series $\sqrt[5]{10}$, or 1.5849

For the 10 series $\sqrt[10]{10}$, or 1.2589

For the 20 series $\sqrt[20]{10}$, or 1.1220

For the 40 series $\sqrt[40]{10}$, or 1.0593

In the 5 series, succeeding numbers represent an increase of approximately 60% over the preceding number; in the 10 series, approximately 25%; in the 20 series, approximately 12%; and in the 40 series, approximately 6%. (The 5, 10, 20, and 40 series preferred numbers are shown in Table 12.)

The progressively larger steps within a preferred number series result in fewer sizes within the overall range of a product or material line. This can mean savings in such items as development, tooling, setup time, and stock keeping.

The numbers in Table 12 are approximations of the theoretical values thus obtained, the departure from the theoretical values being no more than 1.3%. The theoretical values are not given here because they are of no value in the practical application of the system. A table of the "exact" numbers (five decimals) is given in ANSI Z17.1 (see Annex D, Other Documents).

As an example of the application of the preferred number concept, the preferred number 10-series was used to determine the appropriate rational sizes of fillet welds given in the Rational Series column of Table 7. In this case, the series was started at 3 mm (approximately equal to a 1/8 in fillet). The 3 mm was rounded from the table value of 3.15 as a practical consideration. From there on, the sizes 4, 5, 6, 8, etc., result in approximately 25% increase per step. Note that the 13 mm size is superfluous and is not used.

9.3 Value of Using Preferred Numbers. The adoption of a series of preferred numbers to be used by all designers tends to unify sizes chosen by different designers, reduces the variety of numbers used, and creates the uniformity and consequent interchangeability that are indispensable to successful standardization work.

For those working toward the development of metric industrial standards and hoping for possible international acceptance, adherence to the concept of preferred numbers is strongly recommended. To get a multiple variety standard in such mechanical fields as welding accepted by the International Organization for Standardization (ISO), the grading suggested should be consistent with the concept of preferred numbers. For example, a major U.S. producer of roller bearings was forced to change the sizes of a new metric line of roller bearings consistent with a preferred number series as part of an effort to make the suggested standard more acceptable to ISO.

Preferred numbers are recommended for use by smaller industrial units or by individuals wishing to establish rational standardization for their own activity in order to have compatibility with eventual national or international standards.

Changing nonconforming standards that are well established and generally satisfactory requires an evaluation of the advantages and disadvantages in each case. Changes made merely for the purpose of conforming to the preferred number system may not be justifiable in the face of economic disadvantage. Appropriate activity in each situation will be determined by the responsible agency or agency's committee. Serious consideration should be given to the use of preferred numbers for any extension of an existing nonconforming standard. Converting to a preferred numbers system over a transition period may be advantageous for some standards. More details of preferred numbers with applications and approximate calculations can be found in ISO standards 3, 17, and 497 (see Annex D, Other Documents).

Table 12
Basic Preferred Numbers—Decimal Series
(1 to 10)

5-Series (60% Steps)	10-Series (25% Steps)	20-Series (12% Steps)	40-Series (6% Steps)
1.0	1.0	1.0	1.0
			1.06
		1.12	1.12
			1.18
	1.25	1.25	1.25
			1.32
		1.4	1.4
			1.5
1.6	1.6	1.6	1.6
			1.7
		1.8	1.8
			1.9
	2.0	2.0	2.0
			2.12
		2.24	2.24
			2.36
2.5	2.5	2.5	2.5
			2.65
		2.8	2.8
			3.0
	3.15	3.15	3.15
			3.35
		3.55	3.55
			3.75
4.0	4.0	4.0	4.0
			4.25
		4.5	4.5
			4.75
	5.0	5.0	5.0
			5.3
		5.6	5.6
			6.0
6.3	6.3	6.3	6.3
			6.7
		7.1	7.1
			7.5
	8.0	8.0	8.0
			8.5
		9.0	9.0
			9.5

General Note: Percentage steps are approximate averages.

Annex A

Inch to Millimeter Conversion

(This Annex is not a part of AWS A1.1:2001, *Metric Practice Guide for the Welding Industry*, but is included for information purposes only.)

Commonly Used Metric Conversions
(Inch to Millimeter Conversion)
1 in = 25.4 mm exactly
To convert decimal inches to millimeters, multiply the inch value by 25.4.
To convert decimal millimeters to inches, divide the millimeter value by 25.4.

Inch			Inch		
Fractional	Decimal	Millimeter	Fractional	Decimal	Millimeter
1/64	0.016	0.397	33/64	0.516	13.097
1/32	0.031	0.794	17/32	0.531	13.494
3/64	0.047	1.191	35/64	0.547	13.891
1/16	0.062	1.588	9/16	0.562	14.288
5/64	0.078	1.984	37/64	0.578	14.684
3/32	0.094	2.381	19/32	0.594	15.081
7/64	0.109	2.778	39/64	0.609	15.478
1/8	0.125	3.175	5/8	0.625	15.875
9/64	0.141	3.572	41/64	0.641	16.272
5/32	0.156	3.969	21/32	0.656	16.669
11/64	0.172	4.366	43/64	0.672	17.066
3/16	0.188	4.762	11/16	0.688	17.462
13/64	0.203	5.159	45/64	0.703	17.859
7/32	0.219	5.556	23/32	0.719	18.256
15/64	0.234	5.953	47/64	0.734	18.653
1/4	0.250	6.350	3/4	0.750	19.050
17/64	0.266	6.747	49/64	0.766	19.447
9/32	0.281	7.144	25/32	0.781	19.844
19/64	0.297	7.541	51/64	0.797	20.241
5/16	0.312	7.938	13/16	0.812	20.638
21/64	0.328	8.334	53/64	0.828	21.034
11/32	0.344	8.731	27/32	0.844	21.431
23/64	0.359	9.128	55/64	0.859	21.828
3/8	0.375	9.525	7/8	0.875	22.225
25/64	0.391	9.922	57/64	0.891	22.622
13/32	0.406	10.319	29/32	0.906	23.019
27/64	0.422	10.716	59/64	0.922	23.416
7/16	0.438	11.112	15/16	0.938	23.812
29/64	0.453	11.509	61/64	0.953	24.209
15/32	0.469	11.906	31/32	0.969	24.606
31/64	0.484	12.303	63/64	0.984	25.003
1/2	0.500	12.700	1	1.000	25.400

Annex B

Pounds-Force per Square Inch to Kilopascal Conversion

(This Annex is not a part of AWS A1.1:2001, *Metric Practice Guide for the Welding Industry*, but is included for information purposes only.)

Commonly Used Metric Conversions
(Pound-Force per Square Inch to Kilopascal Conversion)
(Thousand Pound-Force per Square Inch to Megapascal Conversion)
1 psi = 6894.757 Pa
To convert psi to pascals, multiply the psi value by 6.894 757 × 10^3.
To convert pascals to psi, divide the pascal value by 6.894 757 × 10^3.

psi ksi	kPa MPa	psi ksi	kPa MPa	psi ksi	kPa MPa	psi ksi	kPa MPa
1	6.9	26	179	51	352	76	524
2	13.8	27	186	52	359	77	531
3	20.7	28	193	53	365	78	538
4	27.6	29	200	54	372	79	545
5	34.5	30	207	55	379	80	552
6	41.4	31	214	56	386	81	558
7	48.3	32	221	57	393	82	565
8	55.2	33	228	58	400	83	572
9	62.1	34	234	59	407	84	579
10	68.9	35	241	60	414	85	586
11	75.8	36	248	61	421	86	593
12	82.7	37	255	62	427	87	600
13	89.6	38	262	63	434	88	607
14	96.5	39	269	64	441	89	614
15	103	40	276	65	448	90	621
16	110	41	283	66	455	91	627
17	117	42	290	67	462	92	634
18	124	43	296	68	469	93	641
19	131	44	303	69	476	94	648
20	138	45	310	70	483	95	655
21	145	46	317	71	490	96	662
22	152	47	324	72	496	97	669
23	159	48	331	73	503	98	676
24	165	49	338	74	510	99	683
25	172	50	345	75	517	100	689

Annex C

Fahrenheit–Celsius Temperature Conversion

(This Annex is not a part of AWS A1.1:2001, *Metric Practice Guide for the Welding Industry*, but is included for information purposes only.)

Commonly Used Metric Conversions
(Fahrenheit–Celsius Temperature Conversion)

$$t_C = (t_F - 32)/1.8$$

$$t_F = (1.8\ t_C) + 32$$

Find the number to be converted (regardless of its temperature scale) in the center (boldface) column.
Read the Celsius equivalent in the column headed "°C" when converting from degrees Fahrenheit.
Read the Fahrenheit equivalent in the column headed "°F" when converting from degrees Celsius.

°C		°F	°C		°F	°C		°F	°C		°F
–273	**–459**		–79	**–110**	–166	9	**48**	118	88	**190**	374
–268	**–450**		–73	**–100**	–148	10	**50**	122	93	**200**	392
–262	**–440**		–68	**–90**	–130	11	**52**	126	99	**210**	410
–257	**–430**		–62	**–80**	–112	12	**54**	129	104	**220**	428
–251	**–420**		–57	**–70**	–94	13	**56**	133	110	**230**	446
–246	**–410**		–51	**–60**	–76	14	**58**	136	116	**240**	464
–240	**–400**		–46	**–50**	–58	16	**60**	140	121	**250**	482
–234	**–390**		–40	**–40**	–40	17	**62**	144	127	**260**	500
–229	**–380**		–34	**–30**	–22	18	**64**	147	132	**270**	518
–223	**–370**		–29	**–20**	–4	19	**66**	151	138	**280**	536
–218	**–360**		–23	**–10**	14	20	**68**	154	143	**290**	554
–212	**–350**		–18	**0**	32	21	**70**	158	149	**300**	572
–207	**–340**		–17	**2**	36	22	**72**	162	154	**310**	590
–201	**–330**		–16	**4**	39	23	**74**	165	160	**320**	608
–196	**–320**		–14	**6**	43	24	**76**	169	166	**330**	626
–190	**–310**		–13	**8**	46	26	**78**	172	171	**340**	644
–184	**–300**		–12	**10**	50	27	**80**	176	177	**350**	662
–179	**–290**		–11	**12**	54	28	**82**	180	182	**360**	680
–173	**–280**		–10	**14**	57	29	**84**	183	188	**370**	698
–168	**–270**	–454	–9	**16**	61	30	**86**	187	193	**380**	716
–162	**–260**	–436	–8	**18**	64	31	**88**	190	199	**390**	734
–157	**–250**	–418	–7	**20**	68	32	**90**	194	204	**400**	752
–151	**–240**	–400	–6	**22**	72	33	**92**	198	210	**410**	770
–146	**–230**	–382	–4	**24**	75	34	**94**	201	216	**420**	788
–140	**–220**	–364	–3	**26**	79	36	**96**	205	221	**430**	806
–134	**–210**	–346	–2	**28**	82	37	**98**	208	227	**440**	824
–129	**–200**	–328	–1	**30**	86	38	**100**	212	232	**450**	842
–123	**–190**	–310	0	**32**	90	43	**110**	230	238	**460**	860
–118	**–180**	–292	1	**34**	93	49	**120**	248	243	**470**	878
–112	**–170**	–274	2	**36**	97	54	**130**	266	249	**480**	896
–107	**–160**	–256	3	**38**	100	60	**140**	284	254	**490**	914
–101	**–150**	–238	4	**40**	104	66	**150**	302	260	**500**	932
–96	**–140**	–220	6	**42**	108	71	**160**	320	266	**510**	950
–90	**–130**	–202	7	**44**	111	77	**170**	338	271	**520**	968
–84	**–120**	–184	8	**46**	115	82	**180**	356	277	**530**	986

(continued)

Annex C (Continued)

°C		°F	°C		°F	°C		°F	°C		°F
282	**540**	1004	560	**1040**	1904	838	**1540**	2804	1116	**2040**	3704
288	**550**	1022	566	**1050**	1922	843	**1550**	2822	1121	**2050**	3722
293	**560**	1040	571	**1060**	1940	849	**1560**	2840	1127	**2060**	3740
299	**570**	1058	577	**1070**	1958	854	**1570**	2858	1132	**2070**	3758
304	**580**	1076	582	**1080**	1976	860	**1580**	2876	1138	**2080**	3776
310	**590**	1094	588	**1090**	1994	866	**1590**	2894	1143	**2090**	3794
316	**600**	1112	593	**1100**	2012	871	**1600**	2912	1149	**2100**	3812
321	**610**	1130	599	**1110**	2030	877	**1610**	2930	1154	**2110**	3830
327	**620**	1148	604	**1120**	2048	882	**1620**	2948	1160	**2120**	3848
332	**630**	1166	610	**1130**	2066	888	**1630**	2966	1166	**2130**	3866
338	**640**	1184	616	**1140**	2084	893	**1640**	2984	1171	**2140**	3884
343	**650**	1202	621	**1150**	2102	899	**1650**	3002	1177	**2150**	3902
349	**660**	1220	627	**1160**	2120	904	**1660**	3020	1182	**2160**	3920
354	**670**	1238	632	**1170**	2138	910	**1670**	3038	1188	**2170**	3938
360	**680**	1256	638	**1180**	2156	916	**1680**	3056	1193	**2180**	3956
366	**690**	1274	643	**1190**	2174	921	**1690**	3074	1199	**2190**	3974
371	**700**	1292	649	**1200**	2192	927	**1700**	3092	1204	**2200**	3992
377	**710**	1310	654	**1210**	2210	932	**1710**	3110	1210	**2210**	4010
382	**720**	1328	660	**1220**	2228	938	**1720**	3128	1216	**2220**	4028
388	**730**	1346	666	**1230**	2246	943	**1730**	3146	1221	**2230**	4046
393	**740**	1364	671	**1240**	2264	949	**1740**	3164	1227	**2240**	4064
399	**750**	1382	677	**1250**	2282	954	**1750**	3182	1232	**2250**	4082
404	**760**	1400	682	**1260**	2300	960	**1760**	3200	1238	**2260**	4100
410	**770**	1418	688	**1270**	2318	966	**1770**	3218	1243	**2270**	4118
416	**780**	1436	693	**1280**	2336	971	**1780**	3236	1249	**2280**	4136
421	**790**	1454	699	**1290**	2354	977	**1790**	3254	1254	**2290**	4154
427	**800**	1472	704	**1300**	2372	982	**1800**	3272	1260	**2300**	4172
432	**810**	1490	710	**1310**	2390	988	**1810**	3290	1266	**2310**	4190
438	**820**	1508	716	**1320**	2408	993	**1820**	3308	1271	**2320**	4208
443	**830**	1526	721	**1330**	2426	999	**1830**	3326	1277	**2330**	4226
449	**840**	1544	727	**1340**	2444	1004	**1840**	3344	1282	**2340**	4244
454	**850**	1562	732	**1350**	2462	1010	**1850**	3362	1288	**2350**	4262
460	**860**	1580	738	**1360**	2480	1016	**1860**	3380	1293	**2360**	4280
466	**870**	1598	743	**1370**	2498	1021	**1870**	3398	1299	**2370**	4298
471	**880**	1616	749	**1380**	2516	1027	**1880**	3416	1304	**2380**	4316
477	**890**	1634	754	**1390**	2534	1032	**1890**	3434	1310	**2390**	4334
482	**900**	1652	760	**1400**	2552	1038	**1900**	3452	1316	**2400**	4352
488	**910**	1670	766	**1410**	2570	1043	**1910**	3470	1321	**2410**	4370
493	**920**	1688	771	**1420**	2588	1049	**1920**	3488	1327	**2420**	4388
499	**930**	1706	777	**1430**	2606	1054	**1930**	3506	1332	**2430**	4406
504	**940**	1724	782	**1440**	2624	1060	**1940**	3524	1338	**2440**	4424
510	**950**	1742	788	**1450**	2642	1066	**1950**	3542	1343	**2450**	4442
516	**960**	1760	793	**1460**	2660	1071	**1960**	3560	1349	**2460**	4460
521	**970**	1778	799	**1470**	2678	1077	**1970**	3578	1354	**2470**	4478
527	**980**	1796	804	**1480**	2696	1082	**1980**	3596	1360	**2480**	4496
532	**990**	1814	810	**1490**	2714	1088	**1990**	3614	1366	**2490**	4514
538	**1000**	1832	816	**1500**	2732	1093	**2000**	3632	1371	**2500**	4532
543	**1010**	1850	821	**1510**	2750	1099	**2010**	3650	1377	**2510**	4550
549	**1020**	1868	827	**1520**	2768	1104	**2020**	3668	1382	**2520**	4568
554	**1030**	1886	832	**1530**	2786	1110	**2030**	3686	1388	**2530**	4586

(continued)

Annex C (Continued)

°C		°F		°C		°F		°C		°F		°C		°F
1393	**2540**	4604		1460	**2660**	4820		1527	**2780**	5036		1593	**2900**	5252
1399	**2550**	4622		1466	**2670**	4838		1532	**2790**	5054		1599	**2910**	5270
1404	**2560**	4640		1471	**2680**	4856		1538	**2800**	5072		1604	**2920**	5288
1410	**2570**	4658		1477	**2690**	4874		1543	**2810**	5090		1610	**2930**	5306
1416	**2580**	4676		1482	**2700**	4892		1549	**2820**	5108		1616	**2940**	5324
1421	**2590**	4694		1488	**2710**	4910		1554	**2830**	5126		1621	**2950**	5342
1427	**2600**	4712		1493	**2720**	4928		1560	**2840**	5144		1627	**2960**	5360
1432	**2610**	4730		1499	**2730**	4946		1566	**2850**	5162		1632	**2970**	5378
1438	**2620**	4748		1504	**2740**	4964		1571	**2860**	5180		1638	**2980**	5396
1443	**2630**	4766		1510	**2750**	4982		1577	**2870**	5198		1643	**2990**	5414
1449	**2640**	4784		1516	**2760**	5000		1582	**2880**	5216		1649	**3000**	5432
1454	**2650**	4802		1521	**2770**	5018		1588	**2890**	5234				

Annex D
Other Documents

(This Annex is not a part of AWS A1.1:2001, *Metric Practice Guide for the Welding Industry*, but is included for information purposes only.)

Bureau International des Poids et Mesures (BIPM): Sèvres Cedex, France

The International System of Units (SI), 7th Edition, 1998.

National Institute of Standards and Technology, Government Printing Office: Washington

The International System of Units (SI), NIST Special Publication 330, 2001.

The approved U.S. translation of the BIPM publication listed above.

Metric System of Measurement: Interpretation of the International System of Units for the United States, National Institute of Standards and Technology, Notice: Tuesday, July 28, 1998, Federal Register, Volume 63, Number 144.

This notice restates the interpretation of the International System of Units (SI) for the United States by the Department of Commerce.

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

Created to assist members of the NIST staff, as well as others who may have need of such assistance, in the use of the SI in their work, including the reporting of results of measurements.

Institute of Electrical and Electronic Engineers, Inc. & American Society for Testing and Materials: New York

Standard for Use of the International System of Units (SI): The Modern Metric System, IEEE/ASTM SI 10-1997.

The primary American National Standard giving guidance for SI usage.

International Standards Organization (ISO): Geneva, Switzerland

Preferred numbers—Series of preferred numbers, ISO 3:1973.

Guide to the use of preferred numbers and of series of preferred numbers, ISO 17:1973.

Quantities and units, Parts 0-13, ISO 31:1992.

Part 0: General principles
Part 1: Space and time
Part 2: Periodic and related phenomena
Part 3: Mechanics
Part 4: Heat
Part 5: Electricity and magnetism
Part 6: Light and related electromagnetic radiations
Part 7: Acoustics
Part 8: Physical chemistry and molecular physics
Part 9: Atomic and nuclear physics
Part 10: Nuclear reactions and ionizing radiations
Part 11: Mathematical signs and symbols for use in the physical sciences and technology
Part 12: Characteristic numbers
Part 13: Solid state physics

Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers, ISO 497:1973.

SI Units and recommendations for the use of their multiples and of certain other units, ISO 1000:1992.

The ISO standard for the International System of Units. Revised periodically.

Society for Manufacturing Engineers: Dearborn

Metrication for Engineers, Ernest Wolff, 2nd Edition, 1983.

A good practical course for learning or teaching SI.

National Institute of Building Sciences: Washington

Metric Guide for Federal Construction

Written specifically for the construction industry and reviewed by metric experts nationwide.

Annex E
Other Organizations

(This Annex is not a part of AWS A1.1:2001, *Metric Practice Guide for the Welding Industry*, but is included for information purposes only.)

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Bethesda, MD 20814-4411
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Fax: 301-656-0989
http://lamar.colostate.edu/~hillger/anmc.htm

Founded under the auspices of ANSI, ANMC is industry sponsored and is the best contact for the effect on industrial standards and industrial transition plans. A purpose of ANMC is to be the principal coordinating body for private industry.

American National Standards Institute
25 West 43nd Street, 4th Fl.
New York, NY 10036
Phone: 212-642-4900
Fax: 212-398-0023
www.ansi.org

ANSI offers a number of publications on metrication including a study of antitrust considerations.

National Institute of Standards and Technology
Metric Program Office
100 Bureau Drive, Stop 2020
Gaithersburg, MD 20899-2020
Phone: 301-975-3690
www.nist.gov

A source of information. NIST publications listed in Annex D may be downloaded free of charge at http://www.physics.nist.gov/cuu/Units/bibliography.html.

U. S. Metric Association, Inc.
10245 Andasol Avenue
Northridge, CA 91325-1504
Phone: 818-363-5606
Fax: 818-363-5606
http://lamar.colostate.edu/~hillger/

Founded in 1916 to promote USA metrication, USMA is a prime source for correct metric system usage, company conversion guideline, and up-to-date information on metric development.

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Annex F
Units for Newton's Second Law

(This Annex is not a part of AWS A1.1:2001, *Metric Practice Guide for the Welding Industry*, but is included for information purposes only.)

Newton's Second Law, which accurately predicts the dynamics of unconstrained objects, can be stated, for the linear motion of rigid bodies of constant mass, as force equals mass times acceleration.

F1. The five coherent sets of units which have been widely used in this equation are expressed in the following five paragraphs:

(1) The newton is the force which accelerates a mass of one kilogram one meter per second squared. The meter, kilogram, and second, (MKS units) are now base units in SI. With the newton, they form an absolute subset of mechanical units in which mass is chosen as a base quantity rather than force because mass can be measured more precisely than force (see 6.2). The newton meter or joule is the unit of energy in SI for all forms of energy.

(2) The dyne is the force which accelerates a mass of one gram one centimeter per second squared. With the dyne, these cgs units also form an absolute subset of mechanical units. The dyne centimeter or erg is the unit of energy.

(3) The kilopond is the force which accelerates a mass of one hyl one meter per second squared. These are European Technical units that are a gravitational subset of mechanical units in which the force of gravity is considered more convenient (although determined with less precision than mass) for some engineering applications. Another name for the kilopond is kilogram-force (kgf). Another name for the hyl is metric-slug.

(4) The poundal is the force which accelerates a mass of one pound (lbm) one foot per second squared. In some older publications, these are called British Absolute units.

(5) The pound-force (lbf) is the force which accelerates a mass of one slug one foot per second squared. In some older publications, these are called British Gravitational units.

F2. All of the units of mass cited above can be expressed as exact multiples of the SI Unit of mass, the kilogram; and all of the units of force cited above can be expressed as exact multiples of the SI Unit of force, the newton. This is accomplished by application of the exact definitions of non-SI Units in terms of SI Units (For example, one foot equals exactly 0.3048 meter.), by application of the "standard acceleration of free fall" (standard acceleration of gravity) 9.80665 m/s^2, and by substitutions in Newton's Second Law.

F2.1 The exact multiples for units of mass are:

(1) One gram = 0.001 kilogram
(2) One hyl = 9.806 65 kilograms
(3) One lbm = 0.453 592 37 kilogram
(4) One slug = 14.593 902 9 kilograms

F2.2 The exact multiples for units of force are:

(1) One dyne = 0.000 01 newton
(2) One kilopond = 9.806 65 newtons
(3) One poundal = 0.138 254 954 376 newton
(4) One lbf = 4.448 221 615 260 5 newtons

F3. Any incoherent mix of units of mass, force, and acceleration can also be made to fit into Newton's Second Law, but the coefficient of each and every factor in the equation can no longer be the number one (1). Two examples follow:

(1) The kilopond is the force which accelerates a mass of one kilogram 9.80665 meters per second squared. Alternatively, the kilopond is the force that accelerates a mass of 9.80665 kilograms one meter per second squared. Note that 9.80665 kilograms is exactly one hyl, which appears in the coherent form discussed in F1 (3) above.

(2) The lbf is the force which accelerates a mass of one lbm 9.80665 meters per second squared. Alternatively, the lbf is the force that accelerates a mass of one lbm 32.175 feet per second squared. Substitutions from the above lists of exact multiples cast this equation into SI form. That is, 4.448 221 615 260 5 newtons equals 0.453 592 37 kilogram times 9.80665 meters per second squared, exactly, where the numerical values reduce to 1, 1, and 1, respectively and exactly.

F4. The weight of a body in a specified reference system is that force which, when applied to the body, would give it an acceleration equal to the local acceleration of free fall in that reference system. (ISO 31-3:1992(E), Item 3-9.2)

F5. Newton's Second Law for rotating objects, for nonrigid bodies, and for objects of changing mass is beyond the scope of this Annex.

Annex G

Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

(This Annex is not a part of AWS A1.1:2001, *Metric Practice Guide for the Welding Industry*, but is included for information purposes only.)

G1. Introduction

The AWS Board of Directors has adopted a policy whereby all official interpretations of AWS standards will be handled in a formal manner. Under that policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

G2. Procedure

All inquiries must be directed to:

Managing Director, Technical Services
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries must contain the name, address, and affiliation of the inquirer, and they must provide enough information for the committee to fully understand the point of concern in the inquiry. Where that point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and should also be in the format used here.

G2.1 Scope. Each inquiry must address one single provision of the standard, unless the point of the inquiry involves two or more interrelated provisions. That provision must be identified in the scope of the inquiry, along with the edition of the standard that contains the provisions or that the inquirer is addressing.

G2.2 Purpose of the Inquiry. The purpose of the inquiry must be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a standard requirement, or to request the revision of a particular provision in the standard.

G2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to quickly and fully understand the point of the inquiry. Sketches should be used when appropriate and all paragraphs, figures, and tables (or the Annex), which bear on the inquiry must be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry must provide technical justification for that revision.

G2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry, or the wording for a proposed revision, if that is what inquirer seeks.

G3. Interpretation of Provisions of the Standard

Interpretations of provisions of the Standard are made by the relevant AWS Technical Committee. The secretary of the committee refers all inquiries to the chairman of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation will be an official interpretation of the Society, and the secretary will transmit the response to the inquirer and to the *Welding Journal* for publication.

G4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal*.

G5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the Standard. The Board of Directors' policy requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. The Headquarters staff cannot provide consulting services. The staff can, however, refer a caller to any of those consultants whose names are on file at AWS Headquarters.

G6. The AWS Technical Committee

The activities of AWS Technical Committees in regard to interpretations, are limited strictly to the interpretation of provisions of standards prepared by the committee or to consideration of revisions to existing provisions on the basis of new data or technology. Neither the committee nor the staff is in a position to offer interpretive or consulting services on: (1) specific engineering problems, or (2) requirements of standards applied to fabrications outside the scope of the document or points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.